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Annual Meeting American Welding Society

The Annual Meeting of the American Welding Society will be held in the Engineering Societies Building, New York, April 24 to 26.

Considerable attention is being given by the Meetings and Papers Committee to insure a large program of technical papers of widespread interest. In order to ascertain the preference of the entire membership of the Society as to the type of papers wanted, a card has been sent to all the members asking them to indicate such preference and to list subjects which they desire to have discussed at the Annual Meeting.

Meetings of several important committees of the Society and the American Bureau of Welding will be held at this time, including Pressure Vessels, Structural Steel and the American Bureau of Welding. The Annual Dinner of the Society will be held on Thursday evening, April 25. Those who attended the last annual dinner can attest to the popularity of this event. Some novel features of entertainment will be introduced.

The complete program of the Annual Meeting will be published in the March issue of the JOURNAL.

Bound Volumes Journal

The Bound Volumes of the JOURNAL for the year 1928 are now ready. This volume includes about 1300 printed pages and contains a Subject and Authors' Index. It is bound in attractive black leather cover. Members may obtain copies at $5.00 per volume. Non-members at $10.00 per volume.

Detroit Engineering Society

The national headquarters have been advised by the Detroit Engineering Society that a recent ruling will permit members in good standing of national engineering societies, including the American Welding Society, to make application for membership in the Detroit Engineering Society without payment of initiation fee. Among the societies included in this list are:

American Society of Civil Engineers.
American Association of Heating & Ventilating Engineers.
American Society of Mechanical Engineers.
American Society of Refrigerating Engineers.
American Institute of Architects.
American Institute of Electrical Engineers.
American Institute of Mining Engineers.
Illuminating Engineering Society.
American Railway Engineering Association.
Society of Automotive Engineers.
The Society of American Military Engineers.
Engineering Institute of Canada.
Association of Iron and Steel Electrical Engineers.
American Welding Society.

American Society for Testing Materials Standards

The American Society for Testing Materials has just issued a bulletin giving an Index to A.S.T.M. Standards and Tentative Standards as of Sept. 1, 1928. The number of these Standards and Tentative Standards has increased to about 548, so that a complete Index seemed desirable. Copies of these Standards may be obtained from the A.S.T.M. by writing to their headquarters at 1315 Spruce Street, Philadelphia, Pa.

Inspecting Welding

(Reprinted from Jan. 10, 1929, issue of Engineering News-Record)

Sir—I notice with interest your editorial on "Welding Inspection" in

the issue of Dec. 27, and as a contribution to the information on the subject of practical methods of inspection of welding, particularly in the field, I wish to say that our experience, which has probably been as extensive as most, has taught us:

First, that it is quite essential that the inspectors have some experience in welding with the various methods.

Second, that before proceeding with the actual work there should be some preliminary welds made and tested to develop whether the actual work when it starts can be produced or duplicated in the manner in which the best of the tests develops.

Third, there should then be welded small sample pieces similar in form to the parts of the structure which are to be erected, these samples to be of a size that the inspector can carry with him and use for comparison of the actual field work.

Fourth, at intervals there should be sample welds made in connection with the construction which could be detached and put through tests and examinations as a check on the uniformity of the work.

The foregoing indicates at least two things: First, that it is going to be some time before there can be anything like uniform data created which would be available for a guide either in the formulation of specifications or in carrying through the actual work; and second, that as in many other important engineering functions, the human element of the personnel engaged in the work is, as indicated in your editorial, very important.

W. R. CONARD,
Conard & Buzby,
Consultants and Engineers for Inspections and Tests of Materials.
Burlington, N. J., Dec. 31, 1928.

SECTION ACTIVITIES

Boston

The February meeting of this Section will be held on the 6th and will be in connection with the Affiliated Technical Societies of Boston and all the societies belonging to that parent body.

The meeting will take the form of an annual dinner and luncheon with technical sessions in the afternoon. The subject will be "Aviation in All of Its Aspects." There will be several prominent speakers and all phases of aviation will be discussed, and a large turnout is expected.

Detroit

A meeting, that will undoubtedly develop as one of the outstanding welding meetings of the year, will be held by the Detroit Section of The American Welding Society, at the University of Detroit, Saturday, Feb. 16, 1929. The meeting is being arranged for the benefit of engineers, architects and students of both professions who are interested in the application of arc welding to the erection of fabricated steel buildings. The meeting will not only include construction and destruction of test specimens, but also an illustrated discussion of the general problem of applying arc welding to building erection by A. M. Candy, general engineer, Westinghouse Electric & Manufacturing Company. Mr. Candy is very prominent in this field of the industry and is very competent to supervise such a demonstration. Further, a moving picture showing the actual operation of the arc and the resultant fusion of the metals, will be exhibited.

For the convenience of those interested, programs will be distributed containing all of the pertinent engineering information relative to the particular specimens to be constructed and tested. Spaces will be provided for recording the results of the tests as they take place, and it is hoped that a great deal of valuable and useful information will be secured, illustrating and proving the merits of electric welding for structural purposes.

Among those directly interested in this demonstration meeting and receiving cordial invitations to participate are the members of the Michigan Society of Architects, Local Sec-

tion of the American Institute of Architects, Engineering Society of Michigan, as well as engineers, students, fabricators and contractors interested in structural arc welding. In view of the interest already shown by builders, a large attendance is expected at the University of Detroit, Feb. 16, 1929.

Philadelphia

The regular monthly meeting of the Philadelphia Section was held on Jan. 21. Paul B. Covey, of the Manchester Engineering & Welding Co., spoke on "Application of Arc Welding to the Fabrication of Structural Steel and Ornamental Iron Work." This was a very interesting paper and a lively discussion followed.

New York

The February meeting of the New York Section will be given over to Aircraft Welding. This meeting will be held on the 5th. A paper of unusual interest will be offered at the meeting on a subject that is interesting to every forward looking citizen as well as all those who are mechanically inclined. Harold A. Backus, head of the materials department of the Curtiss Aeroplane & Motor Co., Inc., Garden City, L. I., will speak on "Welding in Aircraft."

Mr. Backus, who is an authority on this subject, represents a company that is known to all. Not only is it a pioneer manufacturer of American aircraft but has long been one of the largest and most forward looking organizations in this rapidly developing field. Mr. Backus will bring a paper that will be instructive to those who are interested in welding and of value also to engineers or laymen who are interested in the operation or construction of aircraft.

Mr. Backus' paper will be illustrated with a number of splendid lantern slides made from photographs taken at the Curtiss plant. He will also have available actual specimens of welded construction, sample welds and specimen aircraft joints which will be exhibited and explained.

In addition to this, there will be shown three reels of Official United States Army Motion Pictures especially obtained for this meeting direct from the War Department at Washington.

Western New York

The January meeting of this Section was held on the 22d. This was a joint meeting with the American Society of Mechanical Engineers. J. F. Lincoln, vice-president of the Lincoln Electric Company, spoke on "The Effect of Arc Welding on Manufacturing Process."

The lecture was made further interesting by a number of lantern slides, also three reels of moving pictures, all of these showing the various applications of arc welding, particularly as applied to the fabrication of parts, as a portion of the manufacturing process of a large variety of articles made from steel, which formerly had been made from cast iron; pictures and lecture clearly explaining the enormous saving in manufacturing cost as a result of substituting arc welding in the place of castings.

Portland

The Program Committee of the Portland Section has been very active and has some very good material lined up for coming meetings.

For February they will have two films, one from the Petroleum Iron Works of Sharon, Pa., showing heavy vessel welding; and the other from the National Welding Equipment Company of San Francisco, Cal., of the Feather River pipe line.

In March they will show a film produced by the Stoody Company of Whittier, Cal., of the manufacture and use of different welding rods and equipment.

Paul B. Covey, of the Manchester Engineering & Welding Company, Manchester, N. H., is preparing a paper on the welding of ornamental iron. This, it is hoped, will be scheduled for April.

San Francisco

A joint meeting of the San Francisco Section of the A.I.E.E. was held jointly with the American Society of Civil Engineers, American Society of Mechanical Engineers, The American Welding Society, and the Institute of Architects, on Friday, Jan. 25. Professor F. P. McKibben spoke on "Electric Welding of Steel Buildings and Bridges." Professor McKibben illustrated his talk with stereopticon slides. This was a very interesting paper on the application of electrical power in building and bridge construction.

Large Receiver Pipe Arc-Welded

J. G. SMEBY†

ON a large Westinghouse Cross-Compound steam turbine recently placed in service, an 82-in. receiver pipe is used to carry 1,600,000 lb. of steam per hour at forty pounds absolute pressure from the exhaust of the high pressure turbine to the inlet of the low pressure turbine. This pipe was fabricated with the aid of arc-welding.

Figure 1 shows the receiver pipe on the test floor, where it was supported on cribbing to carry the load of the water while the pipe was being hydrostatically tested. No leaks were found at eighty pounds pressure and none have developed in service.

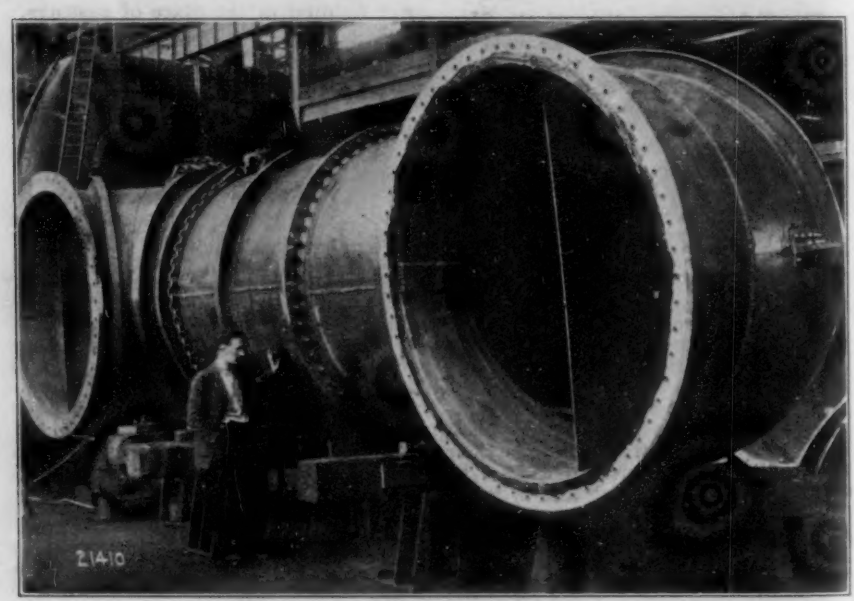


FIG. 1. 82-IN. RECEIVER PIPE

The receiver pipe is made up of two straight sections and two elbows. In fabricating the elbows, the layout was made on the plate, and marked when flat, then rolled into shape. The longitudinal joint was bolted together temporarily at each end and arc-welded the entire length. The butt strap (Fig. 2), was arc-welded in place last, so that no high stresses would be set up in the joint. The sections for the elbows were then cut out along the marked lines with an oxy-acetylene cutting torch. The

†Welding Engineer, Westinghouse Electric & Manufacturing Co.

reasons for this procedure are: that all the rolling is completed in one operation, the welding of the longitudinal joint is done at one time, and that it is very difficult to obtain the same curvature when rolling plates of irregular shapes. This can be easily demonstrated by attempting to roll a half-inch plate with a rectangular hole in it.

In service, stresses will be set up in the flanges by the expansion and contraction of the receiver pipe under various temperature conditions. In order to distribute these stresses more evenly the flanges were lap-welded in place, as shown in Fig. 3.

The change of pressure in the receiver pipe may be from 40 lb. absolute to 29 1/2 in. vacuum, and takes place almost instantaneously when the load is thrown off through some accident such as lightning striking the power transmission line, thereby throwing the circuit breakers out. To take care of such rapid pressure drops, the receiver pipe must be strong enough to prevent collapsing under the sudden vacuum. The first thought was to stiffen the pipe by means of rolled I-beam section and weld in place. This, however, is very difficult and requires expensive shop equipment. It was finally decided that the I-beam section should still be used for circumferential stiffeners, but that it should be built up as in Fig. 4. To build up this section a 3/8-in. thick strap was wrapped around the

FIG. 2. CROSS SECTION OF LONGITUDINAL JOINT

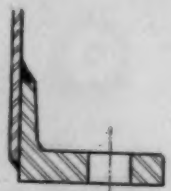


FIG. 3. CROSS SECTION OF FLANGES

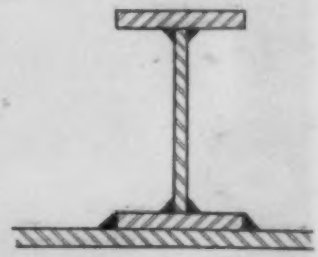


FIG. 4. CROSS SECTION OF CIRCUMFERENTIAL STIFFENERS

receiver pipe and welded in place. The web was made up of six segments 1/4 in. thick, and welded in place. The outer strap was also 3/8 in. thick. This method of construction was found to be a cheap and effective means of fabricating the circumferential stiffeners.

One receiver pipe of this diameter and construction is now in use and has given excellent service, and another of similar characteristics is being furnished for a unit now in course of erection. It is interesting to know that the first receiver pipe was installed without alteration or even the necessity of springing it in place.

The Construction of an Overhead Monorail Conveyor by Use of the Arc Welding Process

JOSEPH W. MEADOWCROFT†

THIS writeup deals with the arc welding method employed in the fabrication and installation of structural steel members which go to make up a standard type of overhead, monorail conveyor.

The use of conveyors of the type hereinafter described is of recent design and development. The process of arc welding this type of equip-

FIG. 1. SHOWS THE SETUP FOR WELDING ONE OF THE STRUCTURAL STEEL HANGERS FOR SUPPORTING THE MONORAIL. THIS UNIT IS COMPOSED OF SIX (6) PARTS AND ALL THESE PARTS ARE TEMPORARILY HELD TOGETHER BY MEANS OF SEVEN (7) "C" CLAMPS AND ALL PARTS ARE SHOWN SETUP AND CLAMPED READY FOR THE ARC WELDING OPERATION

ment has been used from the very first installation ever made completely in our plant and for this reason, no actual comparison has been made between the cost of the arc welding method vs. the riveted method which all conveyor builders, in our experience, have used almost exclusively in work of this nature.

The engineers who design this type of equipment and follow the fabrication and installation, show considerable savings by the use of the arc

†Asst. Works Manager, Edw. G. Budd Manufacturing Co.

welding operation. Installations of similar character, when riveted together, and built by outside concerns, have cost the company practically twice as much as equipment designed, built and installed by the company, and as all such work placed through outside firms is subject to keen competition, it is considered to be very unlikley that there would be 100 per

FIG. 2. SHOWS A CLOSEUP VIEW OF THE TOP OF ONE OF THE CONVEYOR FRAMEWORK COLUMNS. THE STRUCTURAL STEEL MEMBERS EMPLOYED IN THE CONSTRUCTION OF THIS COLUMN TOP ARE THE CHANNEL OR UPRIGHT PIECE, AN ANGLE AND BOILER PLATE TOP PIECE

cent profit to any outside firm making such installations. In fact, several investigations of the costs of such work by outside concerns have revealed that their profit in some cases was only about 5 per cent and in one case a conveyor building concern made practically no profit.

From these statements, every indication can be taken that the arc welding method of fabrication of structural steel effects a considerable saving over riveting, and in addition, provides a stronger and more reliable finished product, and the reason for some of the economies of this method will be readily understood by those who have had experience in

†Asst. Works Manager, Edw. G. Budd Manufacturing Co.

the building of such equipment by a careful study of the photographs which picture the progress of this conveyor installation.

One of the big savings from a labor standpoint, also from the absolute absence of liability to errors, is the fact that there is no laying out, drilling or punching and matching up of rivet holes in the various members of which the structure is composed. The absence of this one feature effects an economy also in the field, as there is no temporary bolting together

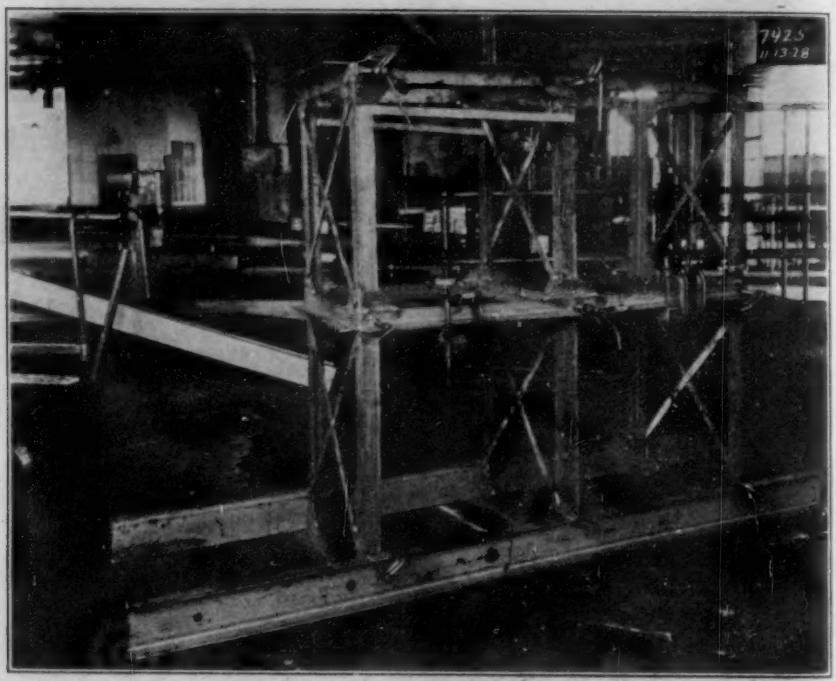


FIG. 3. SHOWS THE FABRICATION OF ONE OF THE SPROCKET CAGES, IN THE CONSTRUCTION OF WHICH THE SAME PROCEDURE OF CLAMPING TOGETHER OF THE VARIOUS MEMBERS OF WHICH THE CAGE IS COMPOSED HAS BEEN FOLLOWED IN THE SAME MANNER AS PREVIOUSLY DESCRIBED

In our experience, when constructing a framework of this type, we have found it most desirable to do a small amount of welding in one location and then immediately do a small amount of welding on another section of the structure as distantly located from the previously welded location as possible, thereby preventing possible distortion on account of throwing a large amount of heat at a concentrated point or locality and allowing the remainder of the mass to be at an atmospheric temperature.
The squareness and parallelism of this nearly finished structure is readily discernible by sighting along the various uprights and longitudinal members of which it is composed.

of the various members, nor the lining up and reaming of rivet holes in the various members of the structure. In the arc welding method, the chief requisite is to have all parts which go to make up the conveyor structure, cut to an accurate length only, and also to adhere to the specification that the various component structural steel parts be straight and flat and true.

method will be readily understood by those who have had experience in

When these last mentioned features are rigidly adhered to, the fabricating of the structure is a very simple procedure and generally requires the services of but two men. The only tools and equipment which these workmen require are the regulation measuring devices, such as scales, tapes, straight-edges, squares and a goodly supply of "C" clamps and,

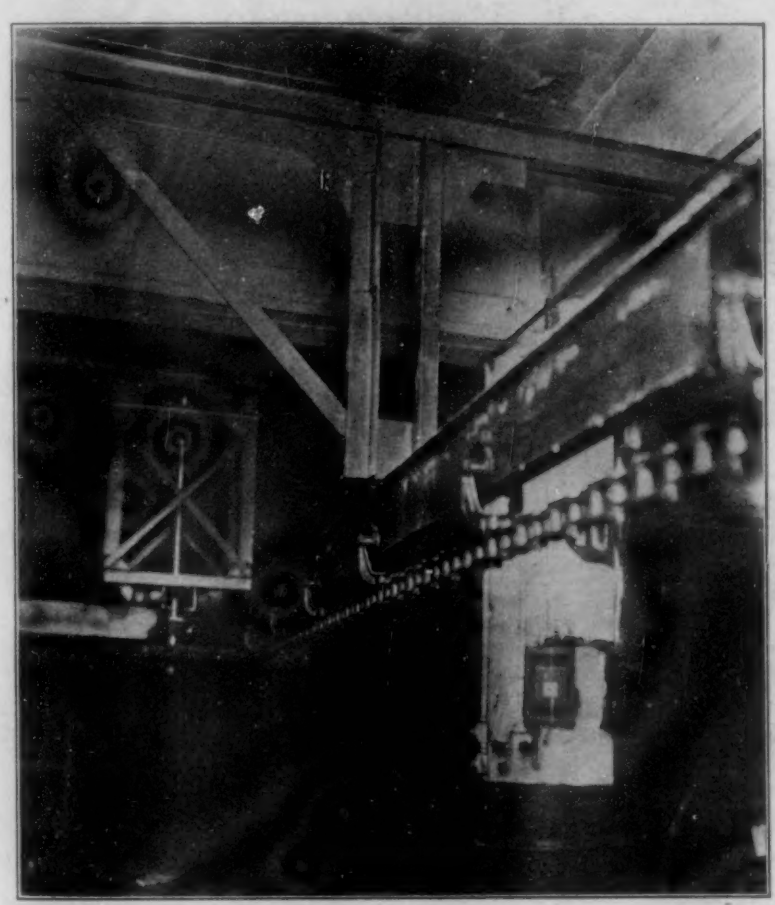


FIG. 4. SHOWS A CLOSEUP OF THE COMPLETELY ASSEMBLED MONORAIL STRUCTURE WITH TROLLEYS AND CONVEYOR CHAIN. THIS VIEW ALSO SHOWS THE METHOD OF SPLICING THE UPPER AND LOWER HALVES OF THE VERTICAL MEMBERS OF THE MONORAIL HANGER AFTER THE SAME HAD BEEN SHORTENED, IN ORDER TO SUIT THE DIFFERENCE IN CEILING HEIGHTS BETWEEN ITS PRESENT LOCATION AND THE LOCATION WHERE THE CONVEYOR INSTALLATION WAS ORIGINALLY INTENDED FOR

of course, the welding equipment of generator, rheostats, welding rods, holder, etc. With this equipment and the necessary blueprints, the construction can be started in the field, if necessary. The simplicity of the construction from entirely raw material of this type of equipment by the arc welding method is illustrated in the photographs.

and flat and true.

The Application of Arc Welding in Production Manufacturing*

A. F. DAVIS†

FOR many years casting and riveting have been regarded as the fundamental processes for making products of iron and steel. And indeed, until the advent of arc welding, there were no other feasible methods of making the many different iron and steel parts which our civilization demands.

Today, however, a new fundamental manufacturing process must be recognized. Arc welding, industry's newest tool, will change manufacturing methods as profoundly as did the substitution of electric motors for steam power plants and water wheels.

In brief, arc welding makes it possible to substitute standard rolled steel shapes in the manufacture of parts that were formerly cast. Furthermore, arc welding makes possible a stronger and more rigid bond between members than is possible by riveted construction. In most instances the application of arc welding reduces manufacturing costs.

These facts are now generally accepted by leading engineers throughout the entire world. Yet even today equipment is manufactured where casting and riveting are employed, solely because the technique of arc-welded design is not generally understood.

Economic pressure is the force which will eventually cause the adoption of arc welding in place of casting and riveting just as any better method always drives out less efficient methods.

Until such time as arc welding is generally adopted, there is a real opportunity for profit for the *first* manufacturer in any line who adopts arc welding since he can offer to his customers a better product and usually a product produced at a lower cost.

It is with the desire to assist those manufacturers who are contemplating the redesign of their product to take advantage of arc-welded construction, that this paper is addressed.

Who Will Be Affected By Redesigning for Arc Welding?

Any change as radical as this one under discussion will affect every department in the manufacturing enterprise.

First of all, the designers and draftsmen must be educated in this method of joining metal. They must learn to resolve complete parts into their components and to determine how rolled steel shapes can be utilized to build up structures of the desired form. But even before this, they

*Abstract of a pamphlet published as a supplement to book, "Arc Welding—the New Age in Iron and Steel," by Lincoln Electric Co.

†Vice-President, Lincoln Electric Co.

must accept the fact that properly made arc-welded joints are as strong and as dependable as the steel in the members joined.

The machine shop and the assembly departments will be affected, and perhaps to some extent disturbed, by the adoption of arc welding. Usually, the amount of machining is greatly reduced by arc-welded design. Assembly time, likewise, is reduced by this method although sometimes more skilled labor is required.

The amount of pattern and foundry work will be, of course, greatly curtailed since practically every cast part can be made of rolled steel sections.

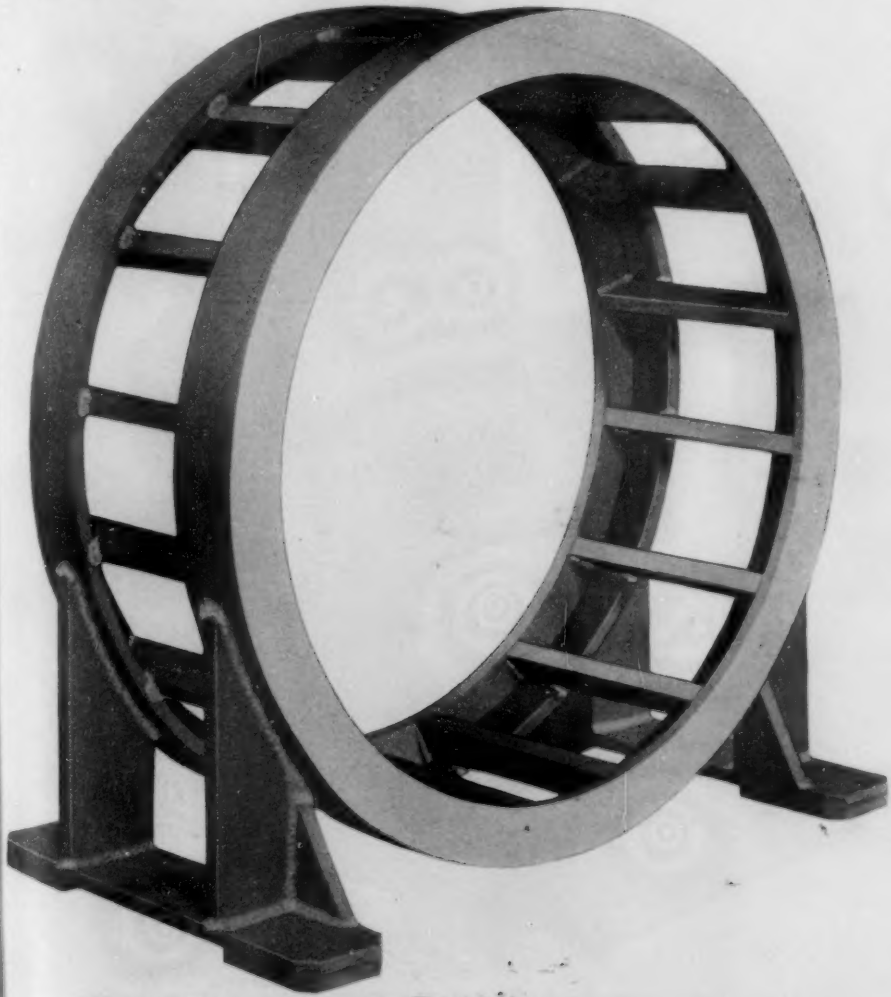


FIG. 1.
Motor frame constructed entirely of standard steel shapes by means of arc welding. This is a production job

The purchasing department and the accounting department will feel the change, particularly because it is possible to operate on a smaller inventory of raw material and semi-finished parts. Immediate delivery can usually be obtained on rolled steel, whereas it has been necessary to anticipate requirements for castings by weeks or months.

The sales department is always interested in any changes which affect selling price and appearance. In some instances the sales manager may anticipate greater sales resistance to an arc-welded product. This might have been the case five or even two years ago, but today the public is coming to accept electric arc welding as synonymous with great strength.

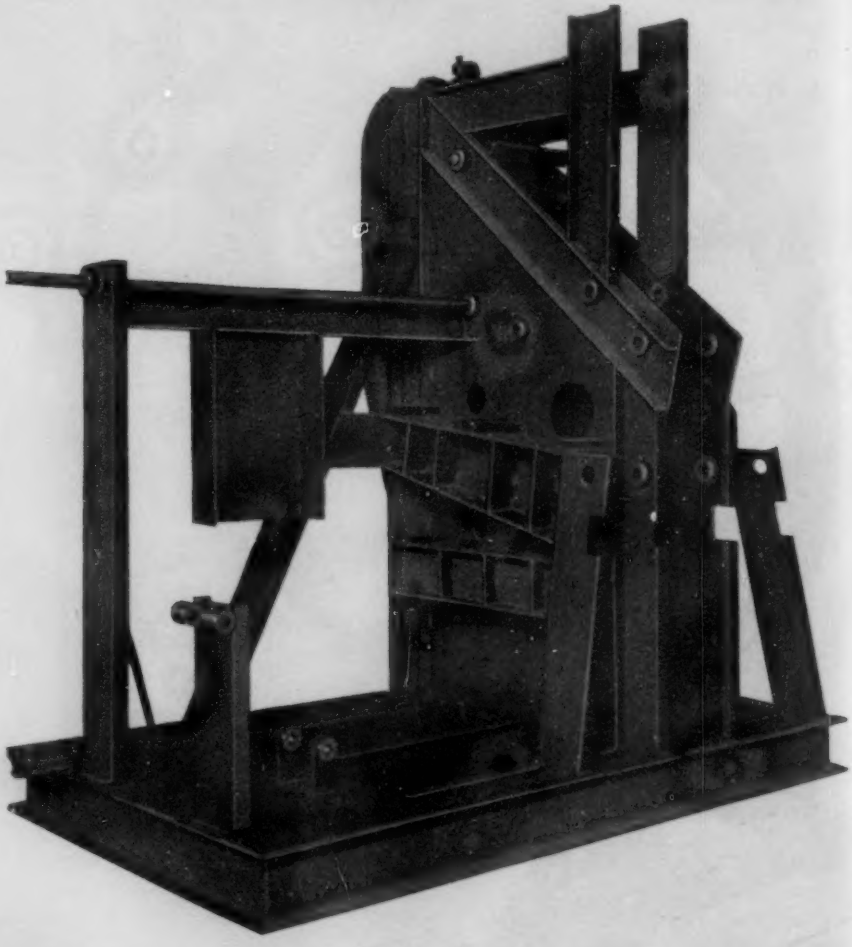


FIG. 2

Special machinery is constructed with marked economy by means of arc welding. The illustration shows the frame for a coke pusher. The arc-welded construction is far more rigid than the conventional riveted design. Further, the design is greatly simplified by welding

FIG. 3

Miscellaneous machine parts made by arc welding. These parts cost far less to make than equivalent castings or forgings. Furthermore, they can be made in a fraction of time since no patterns or dies are required

Turn to the advertising pages of any trade journal in the metal working field and note the number of products that are arc-welded. Note also in how many cases the manufacturer calls attention to the fact that the arc-welding process is used.

An arc-welded product is a superior product and should be sold on this basis. Fortunately it is true that arc welding permits of many economies in manufacturing so that a better product is obtained at a lower cost.

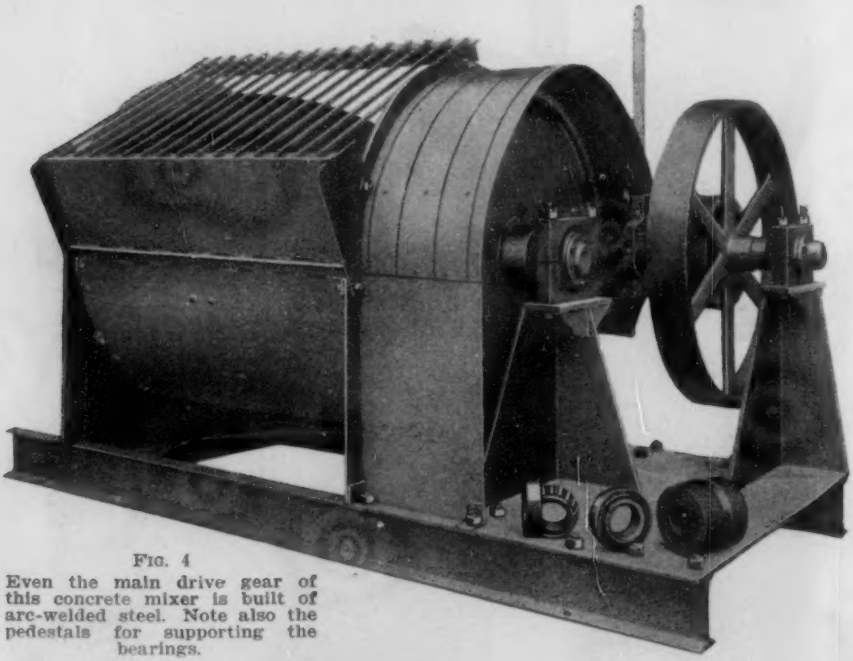


FIG. 4
Even the main drive gear of this concrete mixer is built of arc-welded steel. Note also the pedestals for supporting the bearings.

What Parts Should be Redesigned First?

There are two ways of looking upon the arc-welding process in production manufacturing. First, arc welding may be regarded as an adjunct to present methods of joining metals. Second, arc welding can be regarded as a fundamental manufacturing method to be considered in the original design.

Most manufacturers who started with the first idea are rapidly coming to the second viewpoint, and indeed it is in the complete redesign of products formerly designed for casting or riveting that the greatest profits are realized.

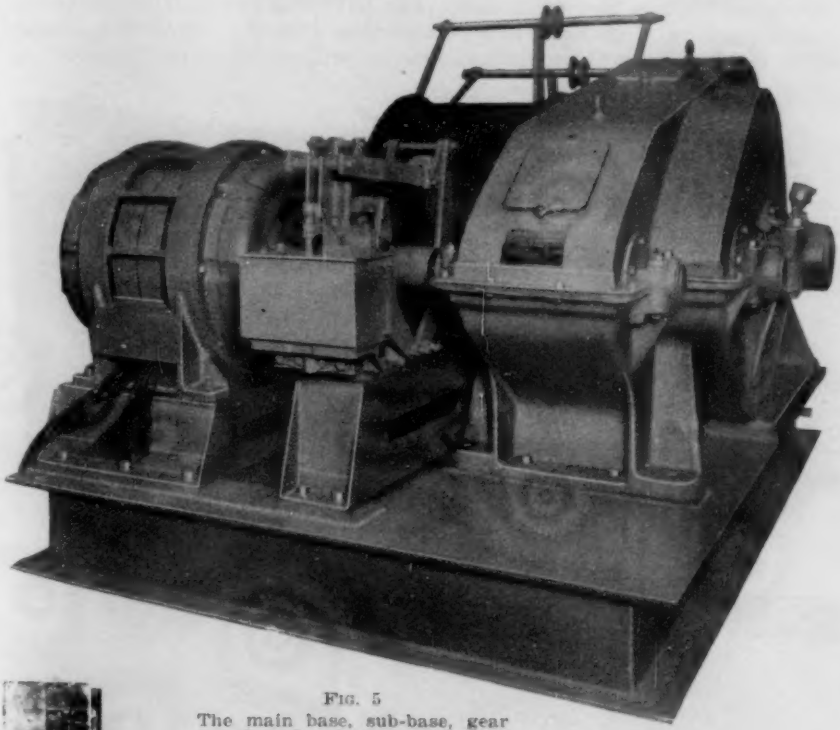
In adopting arc welding as a manufacturing tool the first step is to determine what parts should be redesigned. There are three classes of parts which should be scrutinized to find where it is best to begin. These are:

1. Parts that, because of their form, require a large amount of patterns and expensive foundry work or, in other words, parts where the pattern cost is large in comparison with the total cost.

2. Parts that give difficulty in casting or machining. This classification includes parts that give trouble in use because of breakage or wear.

3. Parts that self-evidently lend themselves to the substitution of steel, such as bases for direct-connected units, stands, brackets, braces, etc.

Above all, the parts first selected for redesign should be simple. The change over from iron to steel requires thought and experience. Weld-



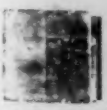


FIG. 5
The main base, sub-base, gear guard and motor on this machine are built of arc-welded steel

FIG. 6
The design of this machinery base is uneconomical because too much welding is employed. A better design is illustrated by Fig. 12

ing technique is not learned in a day, although it is based on plain common-sense principles.

After the part to be redesigned has been decided upon, then the design is to be made. Here is a place where previous experience with cast structures is a great handicap rather than a help. Most castings are made in the shapes finally evolved, not because the stresses have been computed mathematically but because experience has shown that additional metal is needed here and there to overcome difficulties that occur in manufacture or operation.

Shrinkage cracks, for instance, show up at a certain point and the casting is altered to correct this. The part may warp after machining and the design is changed to overcome this difficulty. Breakage in operation or shipping will necessitate heavier sections at certain points. All

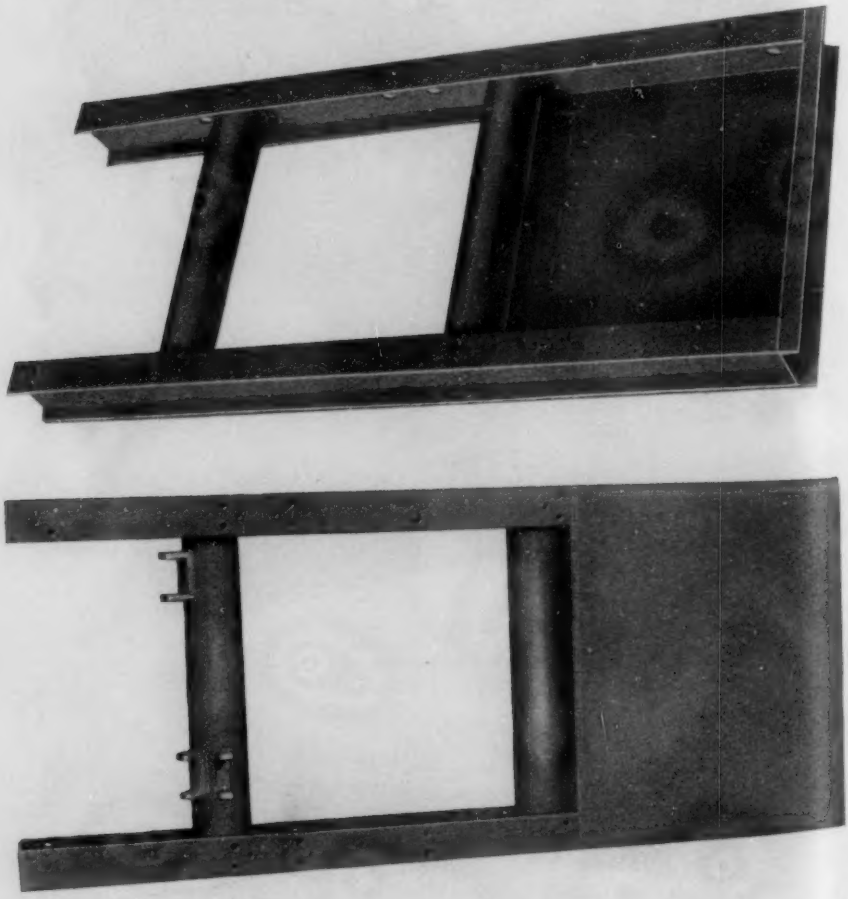


FIG. 7
Arc welding permits the use of tubular braces which are particularly efficient in resisting torsional strains

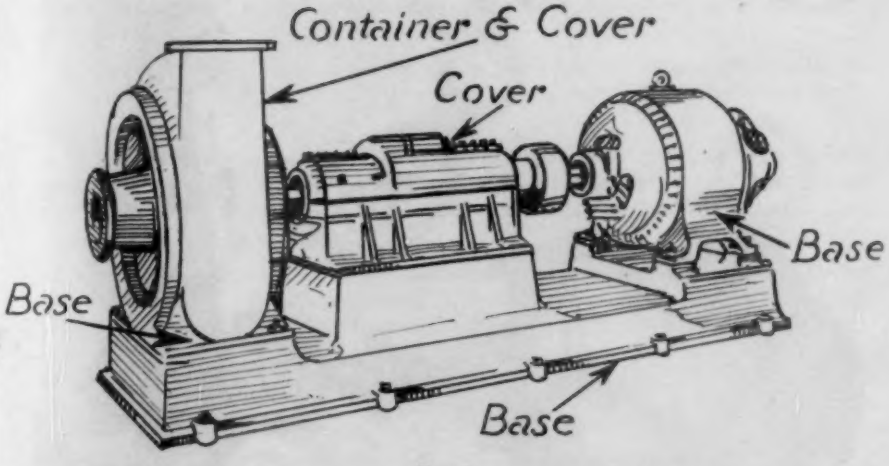


FIG. 8

For convenience in discussing the problem of redesigning for arc welding, all parts are classified as bases, covers, containers or wheels. See text for explanation of this classification

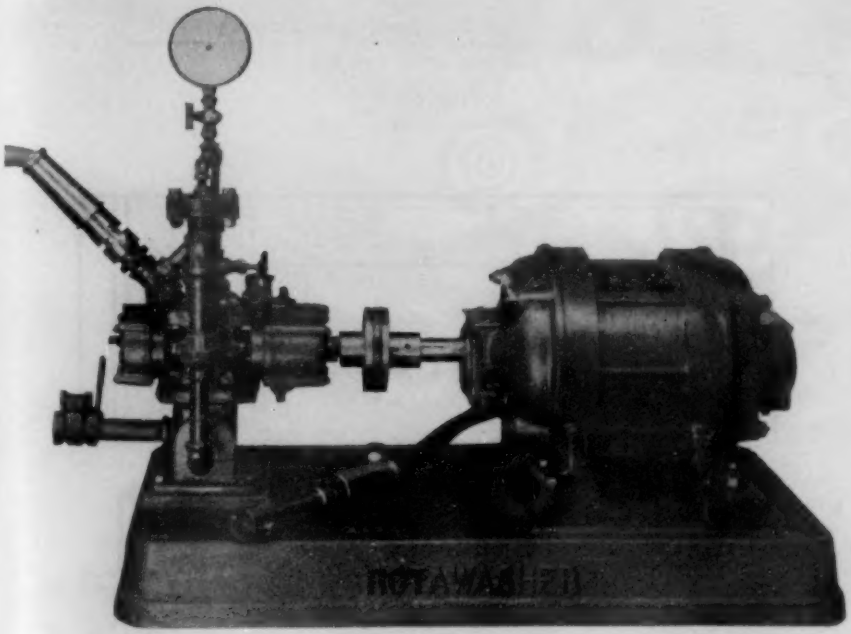


FIG. 9

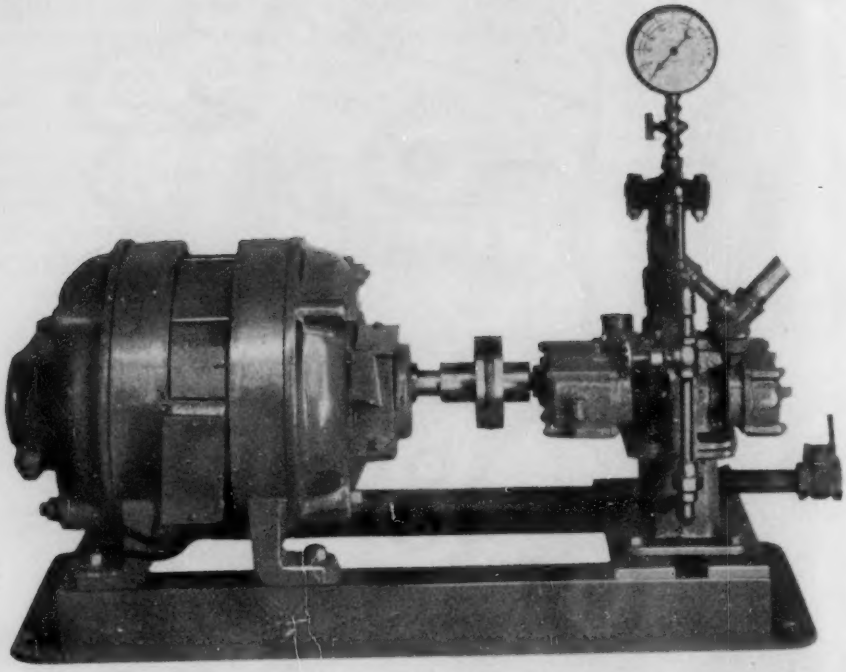


FIG. 10

Bases for direct-connected units are particularly suited for arc-welded construction. Both old and new type bases are shown here. The arc-welded base cost $4 and the cast iron base cost $12

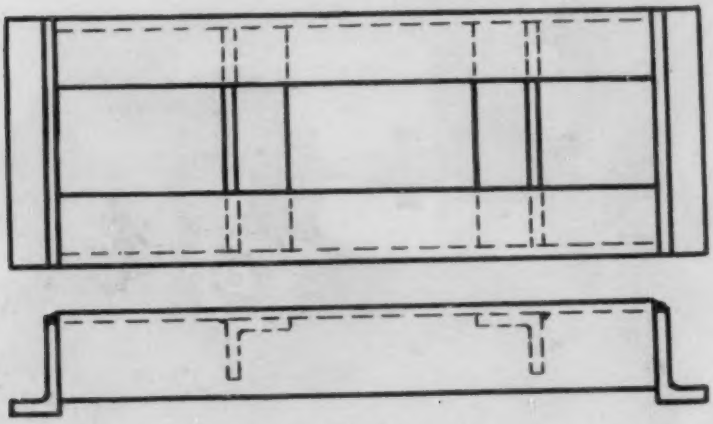


FIG. 11

This is the recommended design for a machinery base where units are to be mounted at the same level

these factors and others contribute to the final design which is the result of experience.

This design may have little or no relation to the actual structural requirements as determined by the load to be carried or the work to be done.

In arc-welded steel construction begin your design by first determining what the loads, or the duty requirements, for part will be. Then design the structure, using the lightest and simplest standard structural steel shapes that can be obtained.

Don't be perturbed if the final appearance of the design as evolved by this straight ahead method is different from its former appearance. After all, sound economical design creates its own beauty. The stage-coach and the full-rigged clipper ship were regarded as beautiful when they were the best available design, but today we think of them as clumsy and absurd when compared with the motor car and the ocean liner. Your customers will not refuse to accept new designs if the design is an improvement over the old.

The deep fillets and flowing curves that characterize cast construction and which in the past we have come to asssociate with beauty of design, were not adopted primarily for the sake of appearance. Manufacturing

FIG. 12
Pads or bosses machined to the proper height are easily welded in place

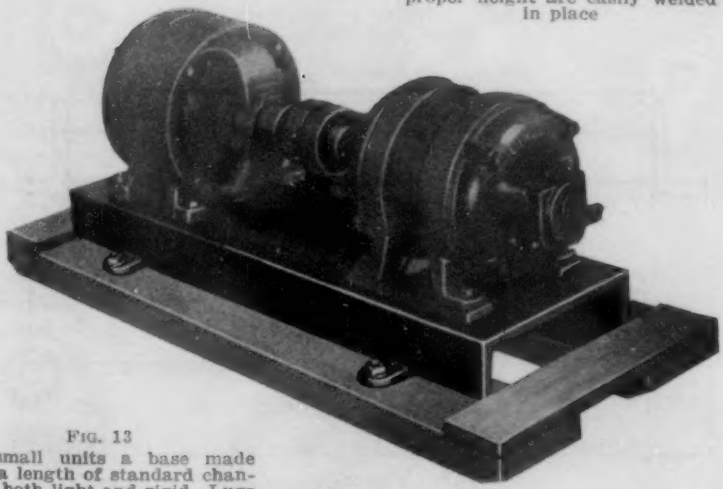


FIG. 13
For small units a base made from a length of standard channel is both light and rigid. Lugs for holding-down bolts are arc-welded as shown

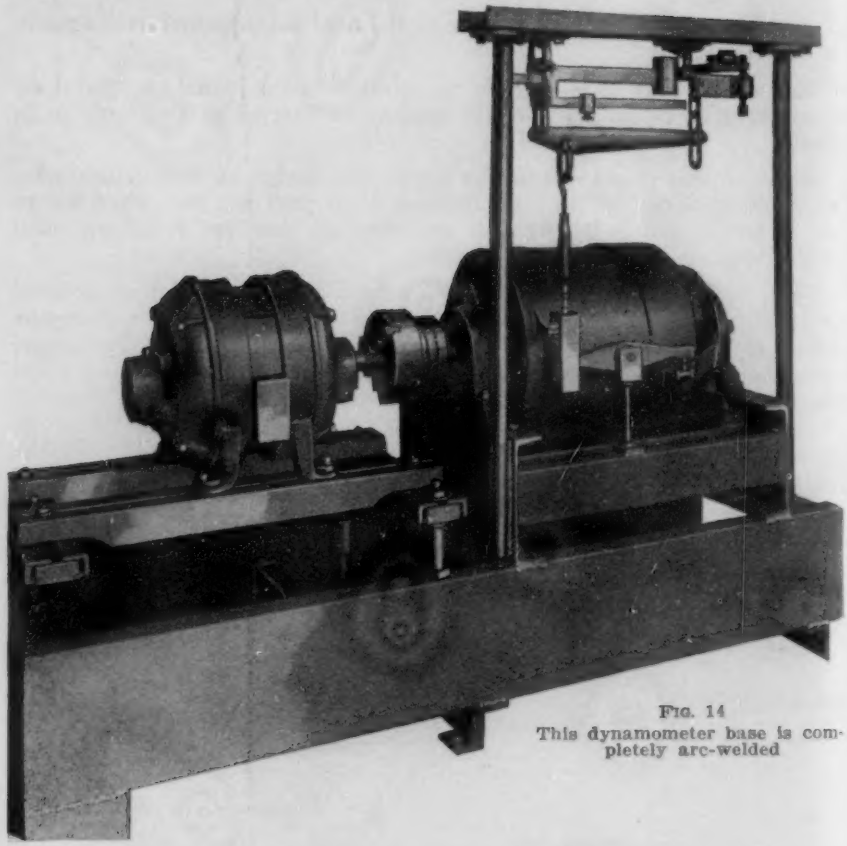


FIG. 14
This dynamometer base is completely arc-welded

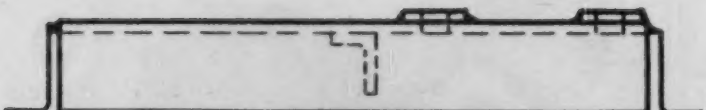


FIG. 15-A

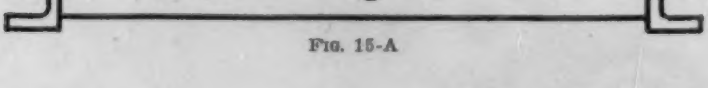


FIG. 15-B
Two methods of building up parts of bases where different elevations are required

difficulties—the problem of drawing the pattern out of the sand—dictated the appearance. Arc welding, because of its different technique, is creating its new standards of beauty.

We mentioned above that arc-welded design is usually more economical than the older methods. This may not be true at the first attempt toward redesign. It is well to keep accurate cost records on experimental work. If the cost of the new design is about the same as the old on the first model built it is probable that subsequent parts will show a considerable

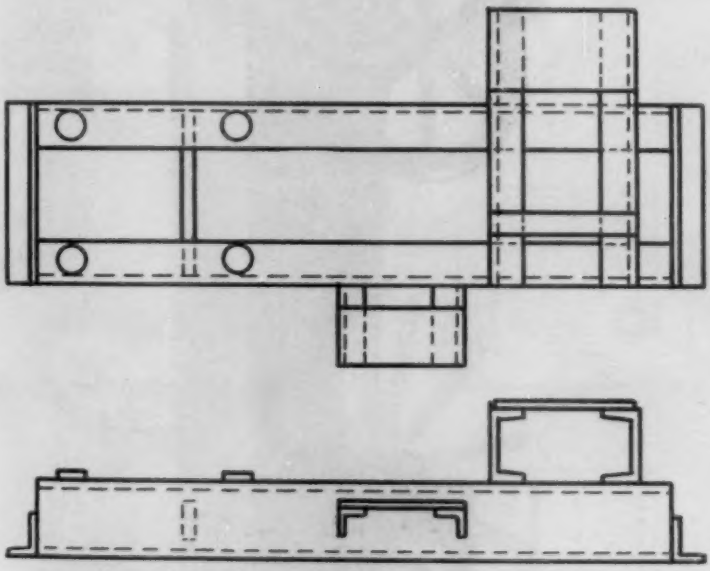


FIG. 16
An arc-welded base with an irregular shape and with sections at different heights

saving. Additional experience in welded design will suggest short cuts which were not thought of at the outset.

Incidentally, the most common fallacy is to specify too much welding. It is surprising how slight modifications in a design will reduce the amount of welding required without impairing the strength of the product.

A point to be borne in mind is that arc-welded design is in its infancy, whereas the technique of casting has been fully developed. Great strides can be expected in arc-welded design as more designers and engineers give it the study that it deserves.

Bases, Covers, Containers and Wheels

For convenience in the following discussion, all parts are classified as either bases, covers, containers or wheels. The classification "bases" covers all parts the purpose of which is to support weight or resist bending.

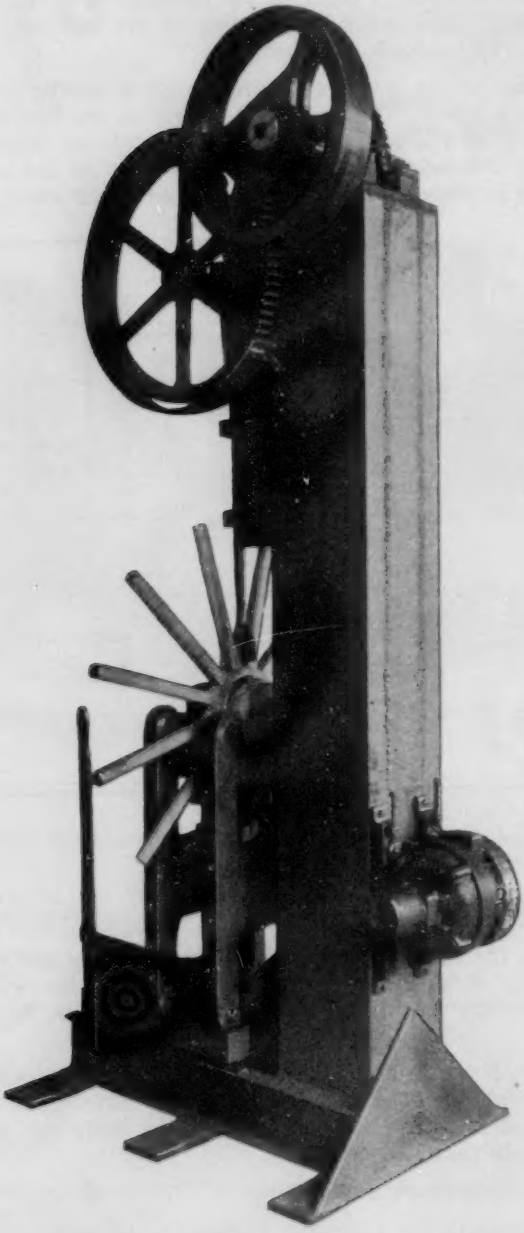


FIG. 17
Where vertical columns are required, standard steel shapes provide great rigidity with light weight

"Containers" are those parts designed to enclose or to resist internal pressure.

"Covers" are those parts which are used to close openings and which are not primarily designed to resist bending or to withstand pressure.

The classification "wheels" is self-explanatory.

A little thought will show that these four classifications are logical and that any part will fall into one or more of these subdivisions.

How to Redesign Bases

At least two-thirds (by weight) of all parts now made of castings or of riveted steel are bases.

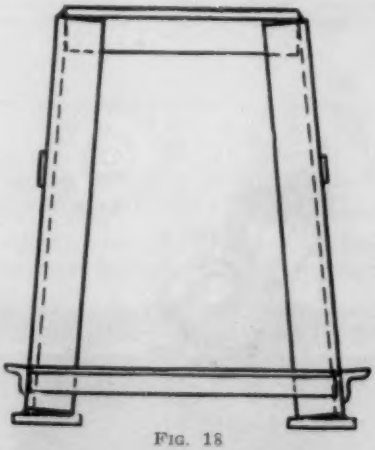


FIG. 18

Standard steel angles lend themselves readily to construction of this sort

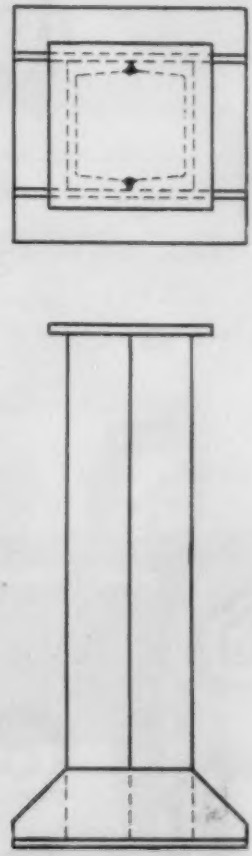


FIG. 19

A vertical column made by arc welding together two standard channels. Base and cover plates are of rolled plate

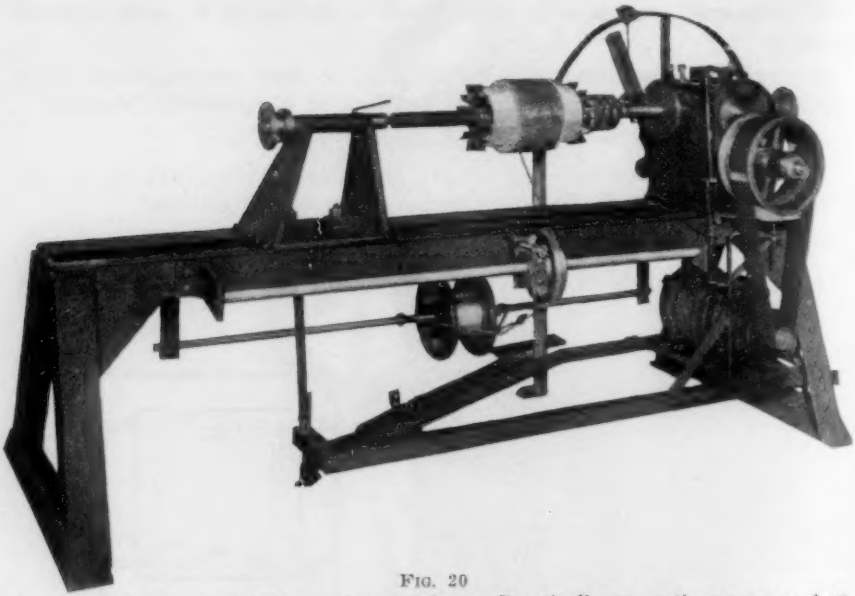


FIG. 20
A special machine for banding motor armatures. Practically no castings were used on this machine. There was no pattern expense to be charged against this job

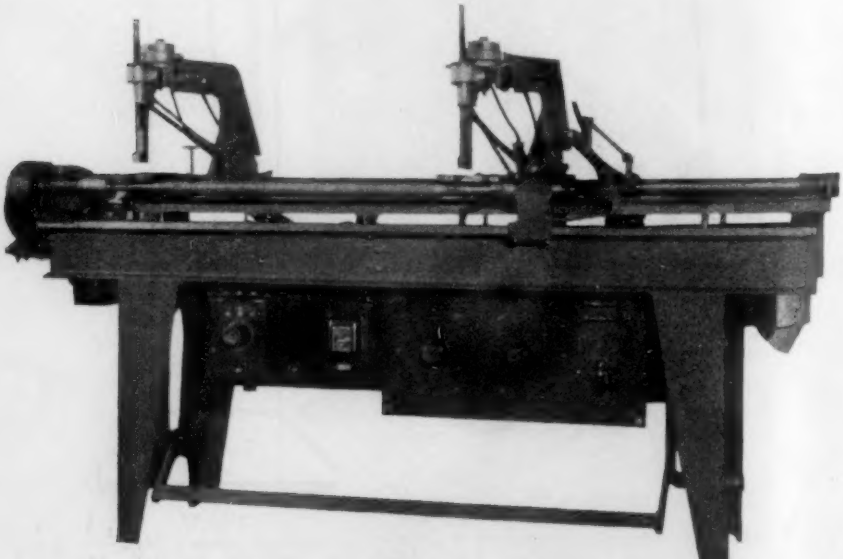


FIG. 21
Special machine built entirely of arc-welded steel

Very often the base is the best part to start to redesign as it represents the largest and most important part of a machine.

A base that has the parts to be supported in a straight line and at the same level is a very simple proposition in welded steel. It is only necessary to cut the proper structural shapes to length and to join the ends by arc welding. Channels, I-beams or H-sections are sometimes used, but angles are usually the best because of the facility with which

FIG. 22-A

FIG. 22-B

Two methods of providing an oil trough around the bottom of arc-welded steel bases

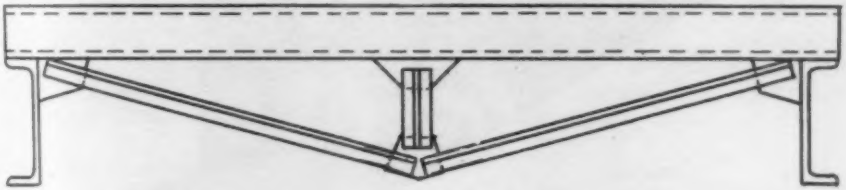


FIG. 23

Material can be saved in the construction of very long bases by suitable bracing as is illustrated here

they can be joined by welding. Cross braces of structural shapes or of tubing will give added stiffness if required.

A simple base of this sort is illustrated in Fig. 11. Holes for the holding-down bolts are drilled through the angles at the ends.

Where it is necessary to have a part of the base higher than the rest, the extra elevation can be added by welding pads or bosses of bar stock. If greater elevation is required, a piece of channel or a complete additional base can be welded in place. (See Fig. 15, A and B.)

When the base must be of irregular shape and of different heights, the general rule to follow is to make the largest possible base of the highest possible uniform height and then to weld additional bases to the main base. Fig. 16 makes this method clear.

The foregoing description covers bases for any sort of direct-connected units such as motor-generator sets, pumps, crushers, etc.

There are other styles of bases which are just as simply designed for arc-welded construction. Columns for supporting various machines are frequently made by welding top and bottom plates to I-beams. Holes for holding-down bolts are drilled through the bottom plates when the column is supported on a floor. Where the column is a part of another

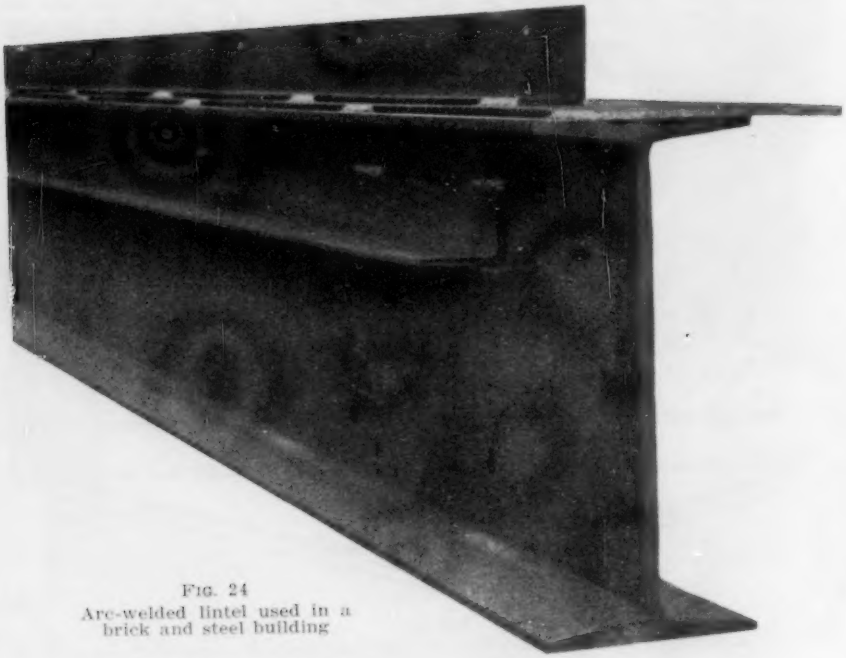


FIG. 24
Arc-welded lintel used in a brick and steel building

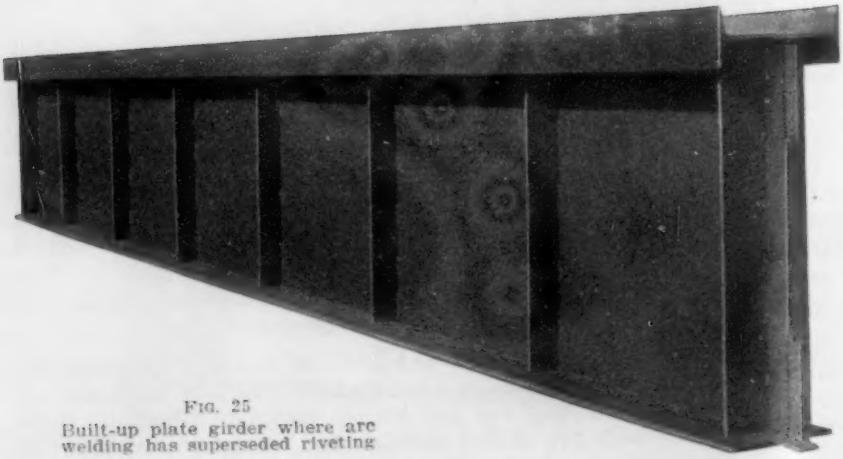


FIG. 25
Built-up plate girder where arc welding has superseded riveting

base, the I beam is arc-welded to the main base by a fillet weld. This construction is surprisingly rigid. Frequently two channels are welded together in the form of a box for columns where extreme resistance to twisting strains must be provided.

Another method of building up stands is to use an assembly of angles as shown in Fig. 18. For the sake of appearance, structures of this sort can be built with tapering sides. There are many variations of the methods of making stands and, once started, the designer will have little trouble in modifying these suggestions to meet his own requirements. Ordinary flat plate sheared to the proper shape is often used to build up pedestals for bearings. This method is sometimes better in appearance, but often the amount of welding is excessive.

Very often on machine tools it is desirable to provide an oil channel around the base. This is very readily done by welding a small standard channel section as shown in Fig. 22. Another method, used when the bottom is a plate, is to weld a thin sheet around the edge and to turn up the edge, welding the corners.

Another class of base that has a wide application is the base that is supported at the ends. If this type of base is enlarged, it becomes a bridge, and the same principles of design apply as for a small machinery base. If the distance between supports is great, the cost of steel becomes great and methods of saving steel must be considered.

FIG. 26-A

FIG. 26-B

Fig. 26-B shows the correct theoretical shape for a beam to resist bending. Such a shape cannot be rolled commercially

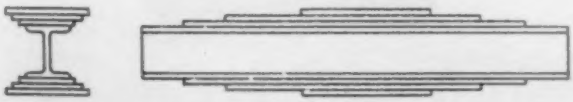


FIG. 26-C

Shows how plates can be arc-welded to a standard rolled shape to give an approximation of the desired theoretical shape

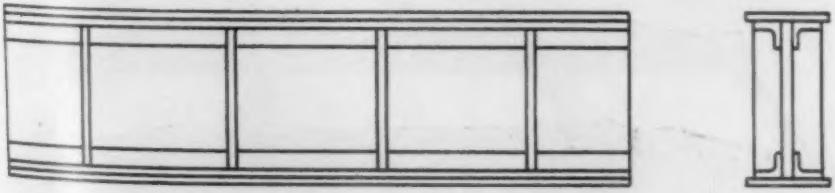


FIG. 27

Design for a built-up plate girder. Flat stock is used instead of angles for the web stiffeners

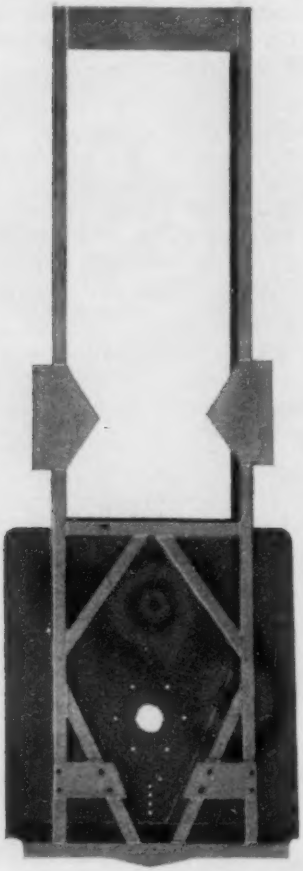


FIG. 28
Base for a completely arc-welded power shovel

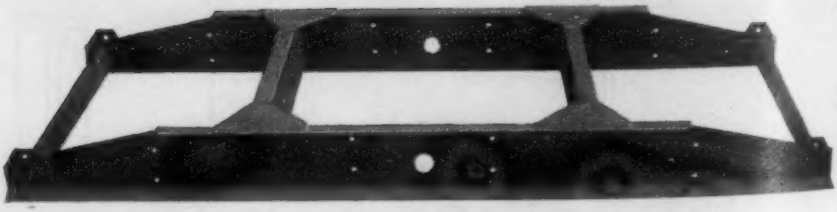


FIG. 29
Arc-welded base for truck crane. This base was formerly riveted

It is evident that, since the bending tendency increases as the distance from the support increases, no standard rolled shape is suitable to give maximum stiffness with minimum weight. The correct form for such a beam is shown in Fig. 26-B. In this theoretical shape the section is the deepest at the center, which is the point where the greatest bending stress occurs.

Obviously such a beam cannot be rolled commercially, but standard beams can be reinforced by means of arc welding to give equivalent strength with light weight. Such a beam is shown in Fig. 26-C. Here flat plates have been welded to the top and bottom flanges of a standard rolled section.

Another method in common use for building up beams is shown in Fig. 27. Here stiffeners are welded to the web of a standard rolled section. Note that flat stock is used for stiffeners instead of angles as

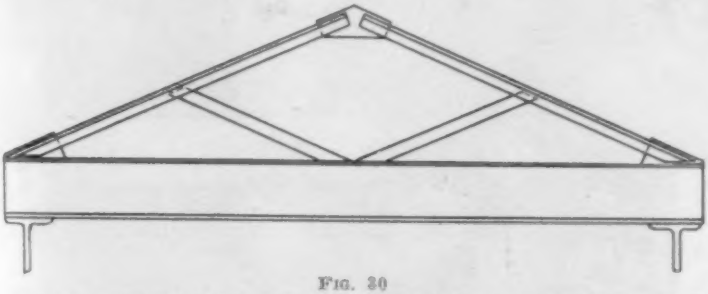


FIG. 30

"Bridge construction" is used for very long bases where the support must be at the ends

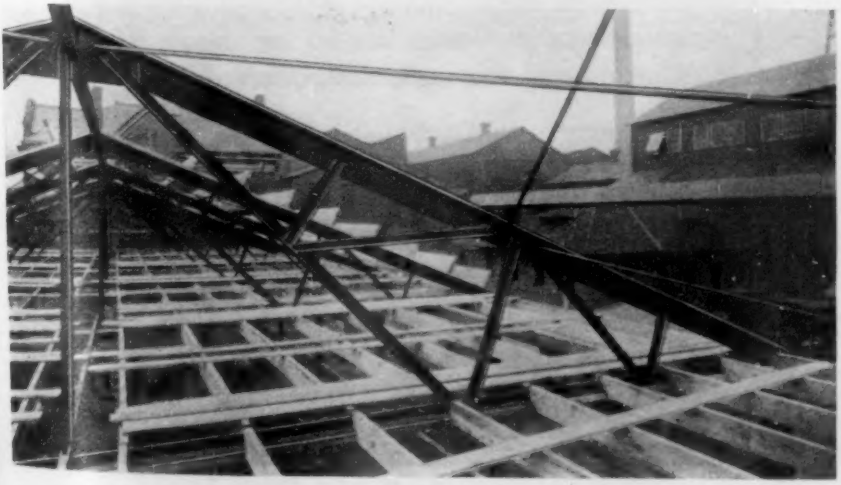


FIG. 31

Arc-welded roof trusses are replacing riveted trusses because of greater strength and lower costs

would be used in riveted construction. On long beams to carry heavy loads, these stiffeners are designed to take the stress directly from the upper flange and not through the web. This is done by filling up the irregular space between the rolled flange and the vertical braces with weld metal.

This construction is very simple by arc welding, but expensive and weak where riveting is employed. In riveted construction, the angles

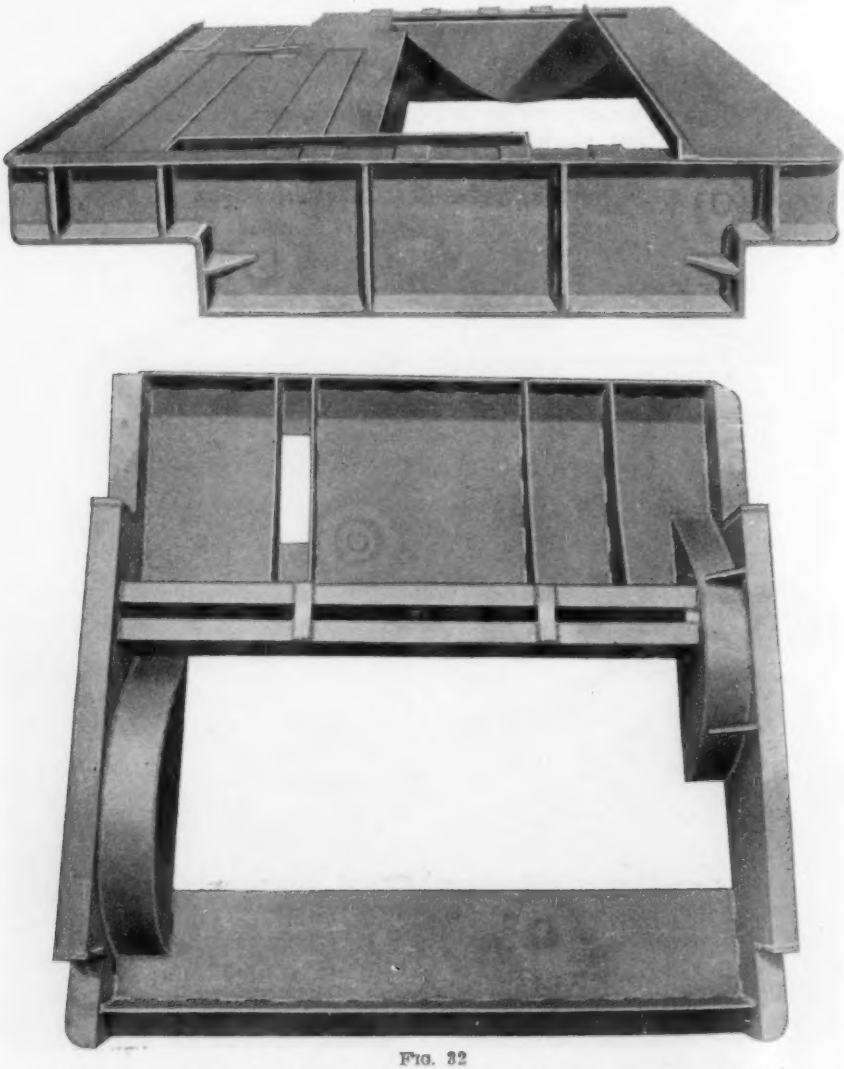


FIG. 32

Trolley frame for a 10-ton 60-foot span overhead traveling crane, built by the Cleveland Crane & Engineering Company, Cleveland, Ohio. Trolley, end trucks and bridge girders are completely arc welded

must be accurately fitted by grinding the ends to make them conform to the shape of the rolled flange.

When very long beams or "bases" are required, it becomes necessary to go to bridge construction using arc welding for strengthening the beams and bringing the parts together as shown in Fig. 30.

In many cases the designer has to choose between a design where considerable welding is required but where the saving in weight of steel is great and a design where less welding but more steel is required. In determining which of the two is the more economical, a balance must be struck between the cost of material and labor.

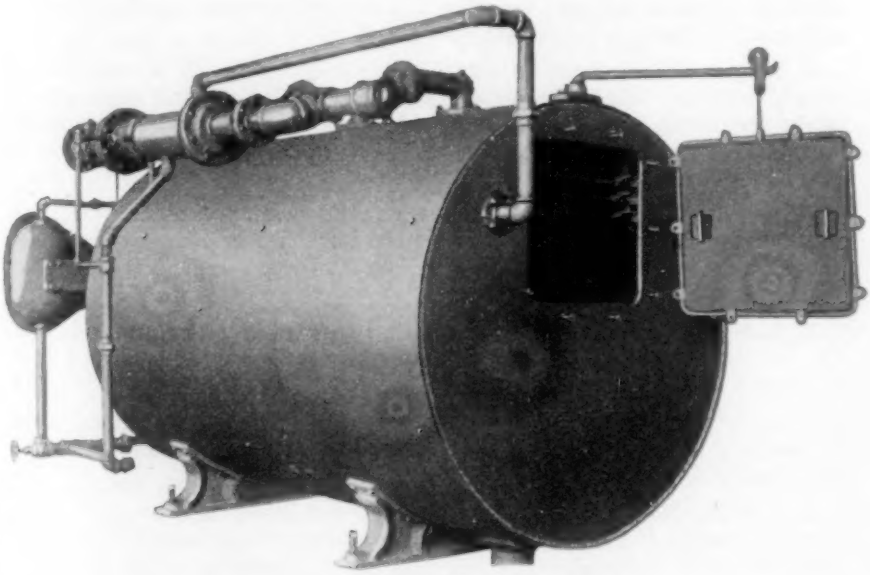


FIG. 33
Arc-welded feed-water heater

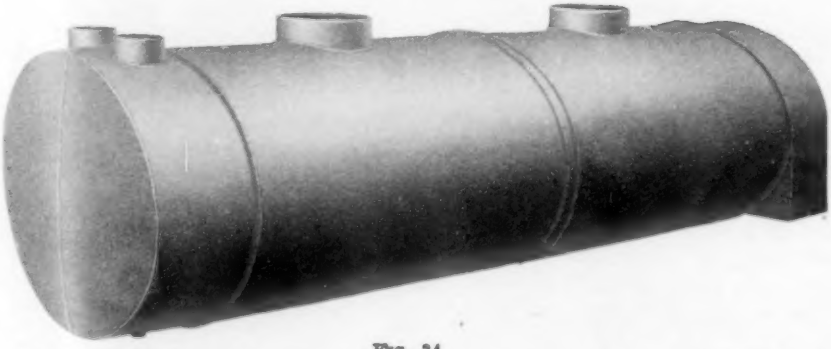


FIG. 34
Tanks of every description are now arc-welded at a great saving over riveted construction. Usually the welding is done by automatic welders

Suggestions

The following suggestions will be found helpful and should be borne in mind when redesigning any base:

1. When machinery is to be drilled or tapped, there is a chance that the web of an I-beam may interfere. Channels or angles are usually more convenient.

2. Do not try to copy the looks of the old part. If it were not wrong you would not be changing it. Design the part to meet its structural requirements and the appearance will take care of itself.

3. The maximum tendency to bend may come at a point where two parts of a base are joined together. A stiffener properly welded in place will give the required strength and rigidity.

4. If you do not want to figure the necessary depth of section and weight of steel, this "rule-of-thumb" method will be found satisfactory: Make the depth of the steel section the same as for cast iron and the weight half as great. If the depth is increased, the weight need never be more than half the weight of cast iron.

5. Avoid forming and bending wherever possible as these increase costs. It will usually be found that the part can be made without any fabrication, except cutting to length, if sufficient thought is given to the design.

6. Use the proper amount of welding to give the strength required. Do not feel that every joint must have a continuous welding bead. Tack welds are surprisingly strong.

7. After the first design has been completed you will find many ways to simplify and improve it. Since there are no patterns, change can be made easily with little expense.

8. Redesigning for arc welding involves fundamental changes and the problem merits the careful thought and study of the best designers in the plant.

Oxy-Acetylene Welding in the Aircraft Industry*

By J. B. Johnson†

THE airplane structure is built up of a large number of parts and a rapid, economical method of joining these parts is essential. Several mechanical and thermal processes, such as riveting, pinning and bolting, soldering, brazing and welding, have been advocated by different constructors and used with varying degrees of success. The process of welding has been in competition with these other methods since the construction of the first airplanes. The welding on some of the first

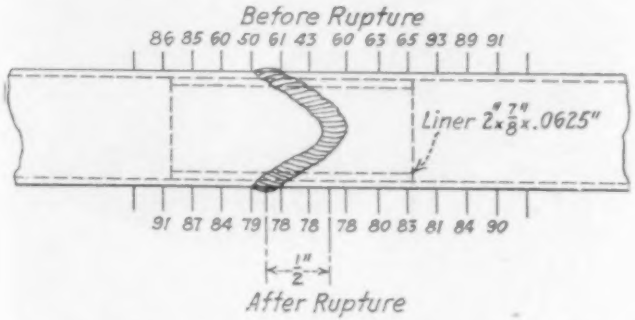


Fig. 1. Readings Taken Before and After the Rupture of a Weld in Tension

sheet-metal fittings was very crude, however, and did not warrant the confidence of the engineers. The application of welding in several industries has forced the development of small, light-weight equipment, increased the facilities for distributing raw materials, and produced a body of mechanics who are skilled in handling an oxy-acetylene torch. The low cost of plant equipment and the ease with which joints could be made in thin metal without elaborate designs or expensive jigs could not be overlooked by the aircraft industry. The advantages of a rigid metal framework were recognized and added further impetus to the use of welding.

The total production of aircraft in this country in 1921 was 302 airplanes. These were practically all typical wooden structures. In 1927 the production was 2353 airplanes, and it has been estimated that this year the production will be from 4500 to 7000 aircraft. The latter figure probably more nearly represents the actual production. Approximately one-fifth will be for the Army and Navy. The remainder are commercial aircraft. Ninety per cent of these modern airplanes will have oxy-acetylene welded steel fuselages, landing chassis, tail skids, and fittings.

*Reprinted from *Airway Age*.
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Problems Involved in Design

The factors which have led to the increase in the use of oxy-acetylene welding in preference to other methods have been stated. The confidence of designers and constructors in the reliability of welding evolved as a result of improvement in design and the eminently satisfactory service obtained with the first welded fuselages or bodies.

The airplane is essentially the product of the engineer and must satisfy the most exacting requirements as to strength and reliability. The improvement in design has been brought about by laboratory tests, metallurgical analysis, and the usual process of trial and error. The

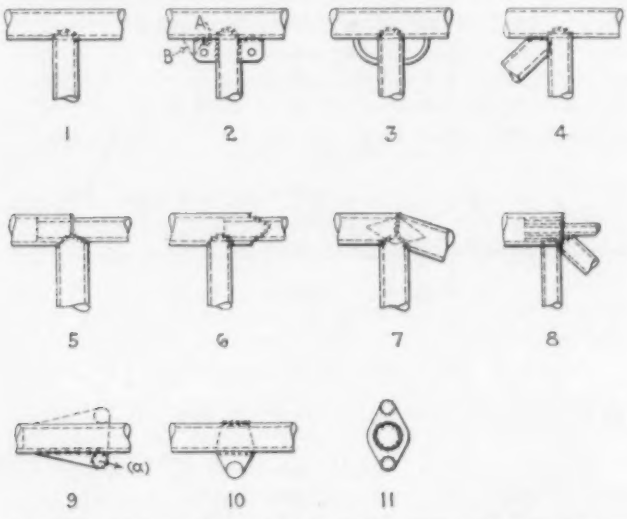


FIG. 2. WELDED JOINT DESIGNS WHICH HAVE BEEN USED SATISFACTORILY

simplest type of joint is a splice, joining two parts. The method of making these splices in sheet metal has been developed for several types of engineering structures, and the designer of the airplane has simply adopted these methods without much modification. The metal is thin and it is seldom necessary to bevel the edges.

In the case of the thin-walled, seamless, steel tubing, methods of splicing have been developed by the aircraft industry. In Table I are given the values taken from an average of about 50 tests representative of the strength of a butt splice. These figures would be different for any combination of data which might be compiled, but the average figure as given in this table should be obtained by any welder competent to weld aircraft parts. The minimum and maximum simply represent the limiting values which are to be expected when testing splices prepared by various welders. The tension test does not always show the true weakness of a joint, as the metal close to the weld which has been softened by the heat of the welding flame will strain-harden during the test and may give a value higher than would be obtained on a similar

joint in compression. This is indicated in Fig. 1 by Rockwell readings taken before and after a tension test of a fish-mouth joint. In aircraft structures the members are welded to form a truss (Fig. 8) and the highest stresses on the principal joints will be compressive. The fish-mouth joint has higher strength under compression than the straight butt weld, since the softening due to the heat is not localized to the same extent.

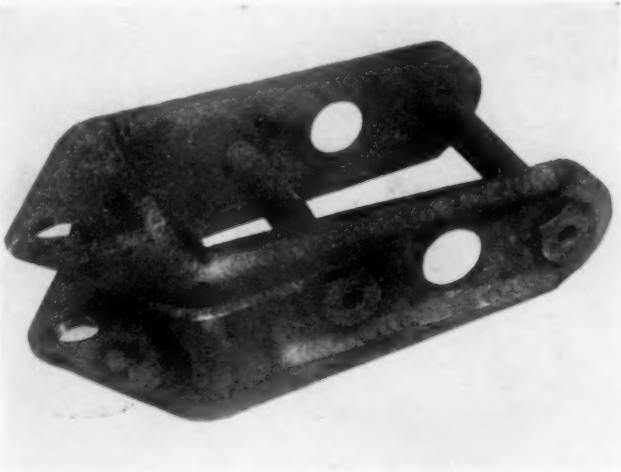


FIG. 3. A WELL-BALANCED DESIGN OF A WELDED FITTING-BREAKING LOAD, 23,300 LB.

An example of the difference between the strength in tension and compression is indicated in the table below, which represents the average of three tests on butt-welded joints. The compression test was made by testing the welded specimen as a short column with the base of the column at one edge of the welded seam. The column collapsed by local failure adjacent to the opposite edge of the welded seam about one-half inch from the point of support.

The tension specimens were pulled in the usual way by gripping both ends of the specimen and pulling with the weld in the middle of the specimen. The tubes used in making the above tests were plain carbon seamless steel tubes containing 0.25 per cent carbon.

Size of tube, in.	1 in. dia., .035 in. wall
Ultimate compressive strength, lb. per sq. in.	48,690
Ultimate tensile stress, lb. per sq. in.	60,960

A butt weld can be considerably strengthened in both tension and compression by incorporating it in a T joint, and in this case the butt joint will have a strength comparable to the fish-mouth joint. This strengthening may be due to the vertical leg of the T or to lugs welded on as terminals for wire tension members, 1 to 4, in Fig. 2. All of the joints shown in Fig. 2 represent designs which have been used satisfactorily. In case the vertical strut is heavily loaded it is advisable to put a telescoping tube inside the horizontal member to reinforce the

joint and prevent local collapse. This is especially important at points where landing gear struts or center section struts are attached.

The tension lugs indicated in 2, Fig. 2, will invariably either tear away the wall of the tube or shear at the pin hole, rather than break in the welded joint, provided the lug itself is properly designed to break the wire tension member. The length of the welded seam should not be decreased by undercutting the lug so that it makes an acute angle with the tube, as shown at dotted line *A*. When a thin sheet is used for the lug and the thickness of the lug is built up by means of a washer

FIG. 4. COMBINED TENSILE AND VIBRATORY TEST ON CARBON STEEL EMPENNAGE FITTINGS

	Solid Fitting	Welded Fitting
Thickness, in.	.125	.083
Amplitude of vibration, in.	.058	.029 .058 .029
Cycles to failure (average)	2,800	260,000 3,600 497,000

or similar device in order to give sufficient bearing for the clevis pins, it is advisable to increase the length of the welded seam, as shown in dotted line B, Fig. 2. This latter scheme sometimes obviates cracking at the edge of the lug. It is a neater design not to have the corner of the lug fit into the corner made by the vertical and horizontal tube. Slotting the vertical tube and making the lugs from one piece increases

the cost and is unnecessary. The lug may also be made of a thin piece of sheet metal bent flat on itself with the bend on the outside and the two legs flared out and welded to the tube.

Tubular members for tension wires, 3, Fig. 2, are used occasionally, but necessitate the use of piano wire which has been practically superseded in this country by cold-rolled or cold-swaged tie rods and standard clevis ends.

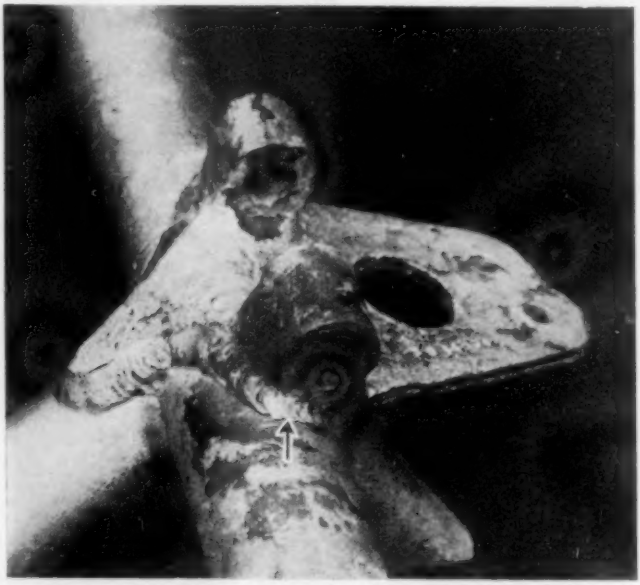


FIG. 5. SERVICE FAILURE OF LOWER LONGERON AT LANDING GEAR ATTACHMENT

The joint represented in 4, Fig. 2, will practically always develop the full tensile strength of all three members. If, however, the number of tubes joined into a cluster of this type are increased, some of the welds are apt to be defective because of the strains caused by the expansion and contraction of the several components on the application of the heat necessary in order properly to fuse the previously welded seams so as to fasten on another member. Fig. 10 represents a cluster of twelve tubes, two of which failed in tension during a sand load test.

Methods of Splicing Tubes of Different Diameters

It is seldom necessary to make a splice in a longitudinal member where the two parts are of the same diameter. Methods of splicing tubes of different diameter are shown in Fig. 2, and these methods will invariably give a joint of 100 per cent efficiency for the smaller member. The telescoping members should project into the tube from 1½ in. to 2 in. The parts should be thoroughly fused together and a few beads of welding metal projecting on the inside of the tube is often a sign of good fusion. A welded seam which is simply stuck on to the outer surface

FIG. 6. FAILURE OF AN AXLE TUBE DUE TO STRAINS SET UP IN A RIVETED JOINT

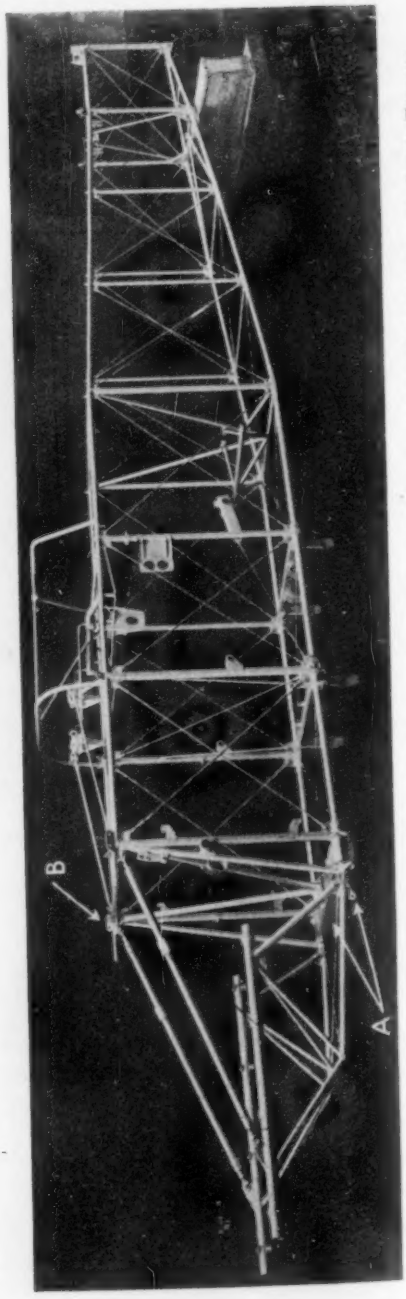


FIG. 8. A TYPICAL WELDED STRUCTURE—ALL CARBON STEEL TENSION LUGS WELDED TO CHROME-MOLYBDENUM STEEL TUBING

of a tube will not develop the full strength of the members in the joint. The results of tests on unreinforced joints in which one member telescopes over the other and the fillet seam is at right angles to the axis of the tube indicate lower strength than for a plain butt weld. The individual results are more erratic, and in testing a welder's skill from the results on a tension test specimen, this type of weld is superior to the straight butt weld.

Tube and Sheet Metal Joints

The extensive welding of sheet metal parts to tubular members has been a more recent development. More failures have been experienced

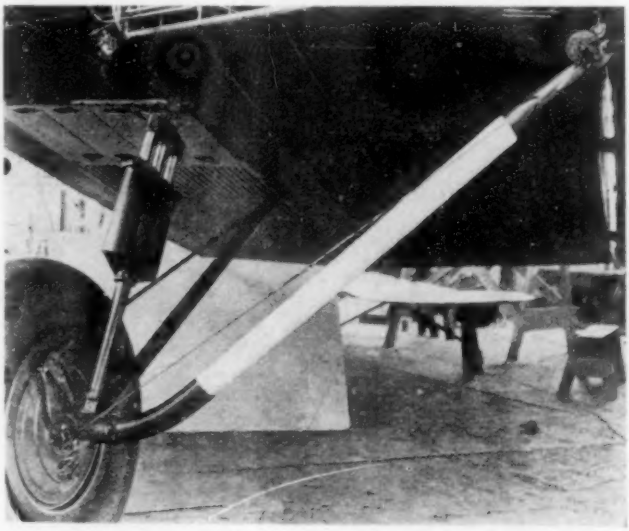


FIG. 7. LANDING GEAR WITH A WELDED AND HEAT-TREATED AXLE

with the improper design of the combination of tube and sheet metal joint than of a joint in which all of its component parts were tubes or sheet. No. 9, Fig. 2, illustrates the method of making a butt weld of a lug directly to a tube. The welded seam should be of sufficient length so that the metal close to the weld will not be stressed beyond the ultimate strength of the material in the lug when in the annealed condition. For 0.25 per cent carbon steel, this may be taken as 50,000 lb. per sq. in. and for chrome-molybdenum steel as 80,000 lb. per sq. in. Using these values, the edge of the lug in contact with the tube will be of sufficient length so that the welded seam will have adequate strength, although made with a low carbon welding wire.

There are certain precautions, however, which should be followed. The line of pull (a) on the lug should not fall outside the edge of the lug so that a couple is produced which will tend to tear the end of the lug away from the tube. In case there is any bending load on the lug, such as would be experienced at a strut point due to flexure in the strut

or due to the actual side load, the tube should be slotted and the lug should be prolonged so that it will pass through the tube as shown by the dotted line in 9 and 10, Fig. 2. It is a good general rule not to use a welded seam in simple tension, but to distribute the load by supporting seams in shear.

TABLE I—VALUES TAKEN FROM AN AVERAGE OF 50 TESTS REPRESENTATIVE OF THE STRENGTH OF A BUTT SPLICE

CARBON STEEL

C—.20 to .30

	Tensile Strength, Lb. per Sq. In.	Yield Point, Lb. per Sq. In.	Elongation in 2 In., Per Cent
(a)	62,000	32,000	35
(b)	45,000	21,000	9
(c)	51,000	26,000	20
(a)	61,000	35,000	34
(b)	51,000	25,000	6
(c)	56,000	35,000	12

CHROME-MOLYBDENUM STEEL

C, .25—.35; Cr, .80—1.10; Mo, .25

	Tensile Strength, Lb. per Sq. In.	Yield Point, Lb. per Sq. In.	Elongation in 2 In., Per Cent
(a)	103,200	68,800	10
(b)	79,100	50,160	2
(c)	88,150	57,600	4
(a)	112,000	80,000	20
(b)	91,000	51,000	2.5
(c)	101,000	69,000	10

Elongation represents actual limiting values and does not accompany the figures for tensile strength.

(a) Maximum.
(b) Minimum.
(c) Average (40 to 50 specimens).

TABLE II—TENSION AND COMPRESSION TESTS ON BUTT WELDS—AVERAGE VALUES

Size of tube, in.	1 × 0.035 wall
Ultimate compressive strength, lb. per sq. in.	28,690
Ultimate tensile stress, lb. per sq. in.	60,960
Minimum letter width	3/5 of the height
Width of stroke	1/6 of the height
Minimum space betweeen letters	1/4 of the height
Approximate length of sign	Height of letter multiplied by number of letters

The application of the above principles can best be shown by a brief analysis of successful and unsuccessful designs. The use of a weld which combines shear and tension is illustrated in Fig. 3. This is a highly stressed wing fitting and is a good example of a weld design which combines light weight and rigidity without the sacrifice of strength.

It is generally assumed that a fitting built of solid sheet metal is stronger than one which has been reinforced by welding, especially

when subjected to vibration. It is interesting to note the tests on two types of tension lugs (Fig. 4). Lug No. 1 was made of sheet metal 0.125 in. thick. Lug No. 2 was made of sheet metal 0.087 in. thick with a washer welded on to increase the bearing area at the pin hole. The tests were made in a special jig attached to an Upton-Lewis fatigue machine. The lug was rigidly bolted at the base and the free end of the pin hole was vibrated while under a tensile load of 840 lb. The amplitude of vibration and the number of cycles to failure are given. Both fittings broke through the pin hole, but the more flexible welded fitting, in spite of the fact that it was of thinner material, gave a longer life.

The concentration of stresses at the juncture of a light and heavy section must be carefully avoided in the design of a welded structure. The weld on the landing gear, Fig. 5, was satisfactory, as indicated by the macroscopic examination of sections cut through the weld. The metal in the lug was more than four times the thickness of the wall of the tube. The failure occurred through fatigue in the tubular member and was due to the design which permitted concentration of stresses at the juncture between a thin-walled tube and a heavy fitting. The failure of the axle tube, Fig. 6, may be ascribed to the strains set up in welding a thin-walled tube to a heavy forging. The natural expansion and contraction was restrained by the rivets. Long tapered joints should be used to distribute the stresses over a large area. The upper end of the axle tube, Fig. 7, is a good example. An accurate stress analysis of a complicated welded fitting is sometimes impossible, and in such cases the fitting should be thoroughly tested before being incorporated in a structure.

The properties of the principal ferrous materials employed for welded parts of aircraft are given in Table III. Medium carbon steel is prefer-

TABLE III—THE PROPERTIES OF THE PRINCIPAL FERROUS MATERIALS USED FOR WELDED AIRCRAFT PARTS

Physical Properties			Welded Forms
Tensile Strength, Lb. per Sq. In.	Yield Point, Lb. per Sq. In.	Elongation in 2 In., Per Cent	
40,000	24,000	35	Water jackets, exhaust stacks, miscellaneous, unstressed parts.
55,000	36,000	22	Fittings, lugs.
	—Annealed—		Tail skids and miscellaneous parts to resist abrasion.
125,000*	100,000	10-over ¼ 5-under ¼	Lugs, fittings.
125,000*	100,000	15-over ¼ 10-⅛ to ¼ 6-under ⅛	Fittings, lugs.
110,000*	80,000		Fittings, lugs.
55,000	36,000	22	Structural parts; axles.
95,000	60,000	10	Structural parts; axles (often heat-treated).
125,000*	100,000	12	Structural parts; axles (use limited).

* After heat treatment. Welding generally done before heat treatment.

able to low carbon steel, in that it requires less cold-working in the final rolling or drawing operation to obtain the physical properties specified, and as a result a higher tensile strength is retained after the steel is subjected to the heat of the welding torch.

Chrome-molybdenum steel has air-hardening properties and the rapid cooling of thin sections in air promotes a strength and toughness at the welded joint which are lacking in the carbon steel. The use of chrome-molybdenum alloy steels in both the form of sheet and tube is increasing rapidly, due to this desirable characteristic. Several grades of welding

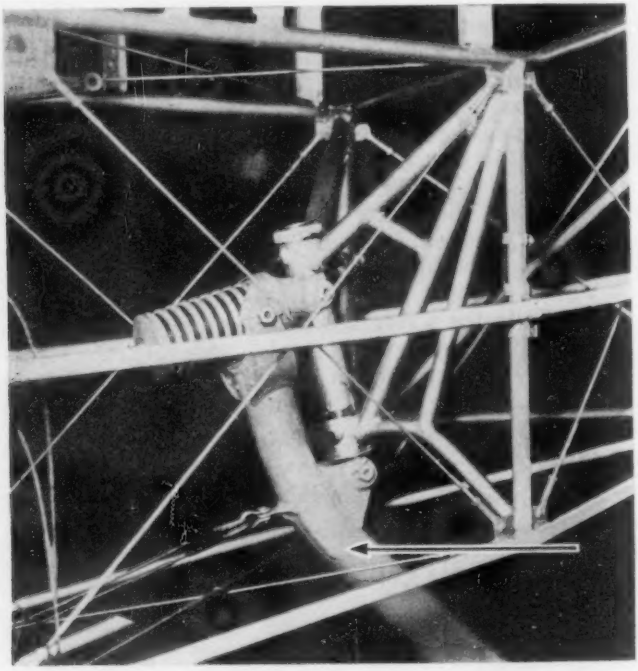


FIG. 9. A HEAT-TREATED TAIL SKID

wire containing less than 0.18 per cent carbon, 0.60 per cent manganese, 0.040 per cent sulphur and phosphorus have been uniformly satisfactory. A carbon content of less than 0.10 per cent is preferred by most welders. With thin material the thickness of the deposited metal is generally from 50 to 100 per cent greater than the base metal and therefore the actual strength in the seam is sufficient without the use of alloy steel welding rod. Experiments with butt welds made with vanadium and chrome-molybdenum welding rods and tested in a rotating beam machine indicate no superiority in the fatigue resistance of the seams made with the alloy steel wire. All specimens broke in the middle of the seam formed by the deposited metal.

The fuselage and other large welded structures are not annealed or

otherwise heat-treated at the joints. There is a pronounced change in metallographic structure between the deposited metal and the part adjacent to it. This probably represents an undesirable condition, but it is questionable whether it has a detrimental effect on the serviceability of the joint. The annealing of a tubular joint would tend to anneal the members at a distance from the weld, with a corresponding reduction in yield point, which would reduce the load-carrying capacity of the tube as a short column.

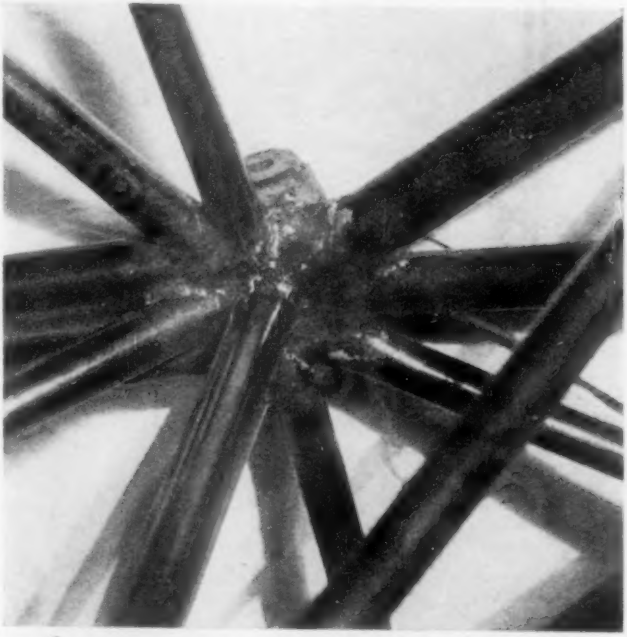


FIG. 10. A TUBE CLUSTER SHOWING THE CHARACTER OF THE FAILURE

The heat treatment of welded parts by quenching and tempering in order to increase the tensile strength and thus permit the use of higher stresses is being done to a considerable extent. Sub-assemblies whose components are highly stressed members in the fuselage supporting the landing gear or engine bearers may be heat-treated and subsequently welded into the fuselage structure. The material in the joint immediately adjacent to the seam will be softened, but the other parts of the structure will retain the full strength obtained by heat treatment. Sub-assemblies similar in design to Sections A and B of the front section of the fuselage, Fig. 8, are heat-treated to develop a tensile strength of 125,000 lb. per sq. in. before being attached to the structure. The axle shown in Fig. 7 represents a type of welded joint which can be satisfactorily quenched and drawn without cracking to develop a unit stress of 200,000 lb. per sq. in. The welded tail skid assembly, Fig. 9, was heat-treated to develop a tensile strength of 180,000 lb. per sq. in.

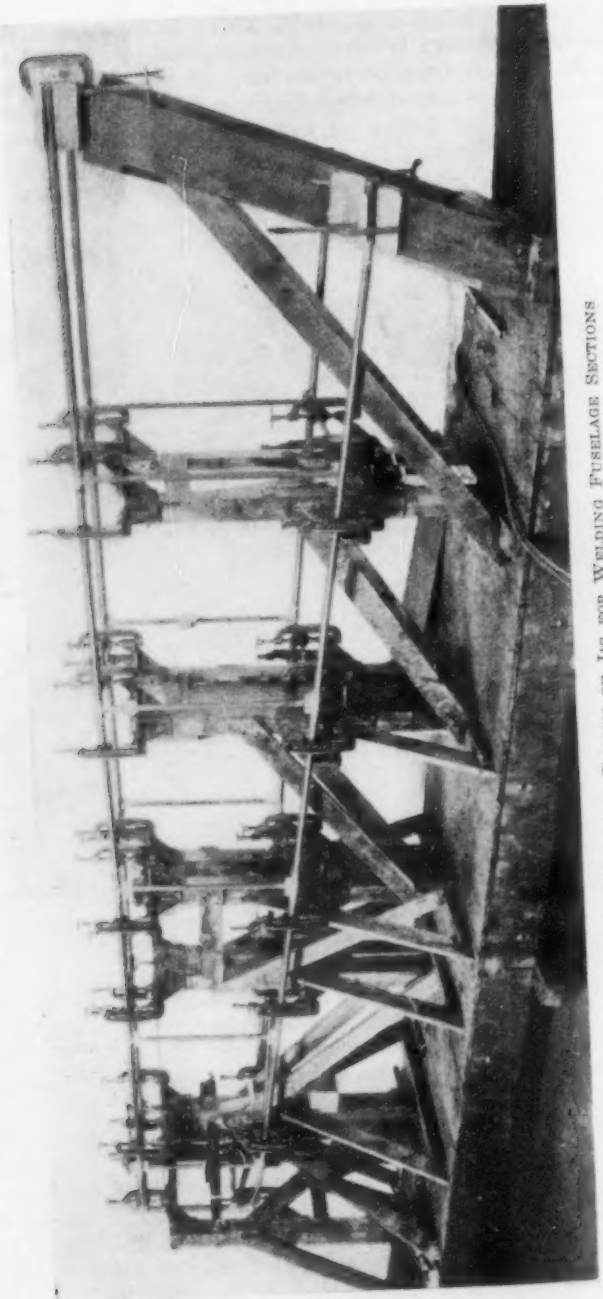


FIG. 11 PRACTICAL DESIGN OF JIG FOR WELDING FUSELAGE SECTIONS

The oxy-acetylene welding of aircraft parts does not require welders of extraordinary skill. A mechanic accustomed to welding heavy sections will have difficulty at first, but a careful selection of the correct welding tip and a short period of training on simple joints are sufficient. The quality of a welder's workmanship should be checked by tensile and ductility test specimens prepared at frequent intervals. The specimens may be in the form of plain butt or fillet welds and also longitudinal seam welds.

The assembling of small parts for individual fittings and of the larger components of the structure is done in jigs, such as shown in Figs. 11

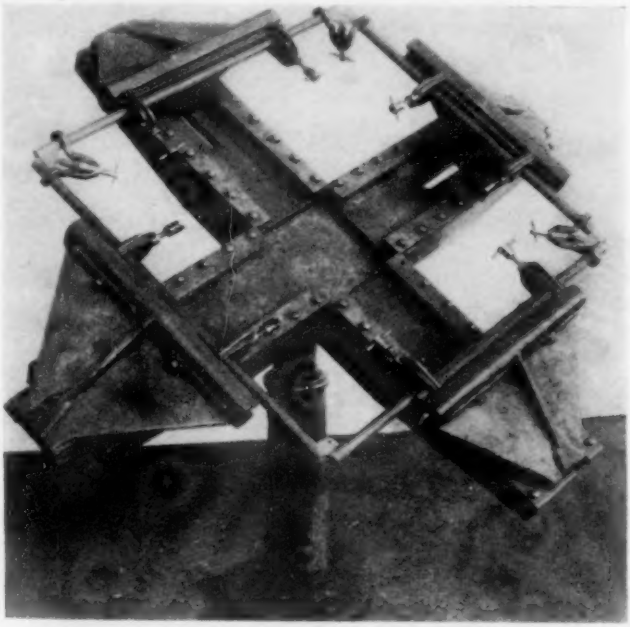


FIG. 12. TYPE OF JIG FOR SMALL ASSEMBLIES

and 12. The various pieces are cut to size. The ends of the tubes and sheet metal are machined square and filed free from burrs and feather edges. The surfaces are cleaned of paint, scale and other foreign matter. The pieces are clamped in jigs and tack-welded. The sequence in which several seams are welded is important, and changing the order may eliminate cracking and distortion. A small torch which can be used in corners is most useful, and tips, drill sizes No. 71, 68 and 58, can be used for metal up to ⅛ in. thick. Tips with drill sizes No. 55, 53 and 51 are better suited for work on thicker sheets, tubes, machined parts, and forgings. As a welder becomes more skillful he can use a larger tip and work faster.

The welding time on an airplane will be from a minimum of 100 hr.

on a small single seat plane to 2000 or more hours on a large transport or cargo airplane.

Repairing a Welded Fuselage Structure

The low cost of maintenance caused by the use of welding cannot be over estimated and will be of increasing importance in the operation of commercial aircraft. A study of the relative costs of a general overhaul on wooden fuselages and welded steel fuselages show a difference of from 15 to 25 per cent in favor of the latter. An airplane structure,

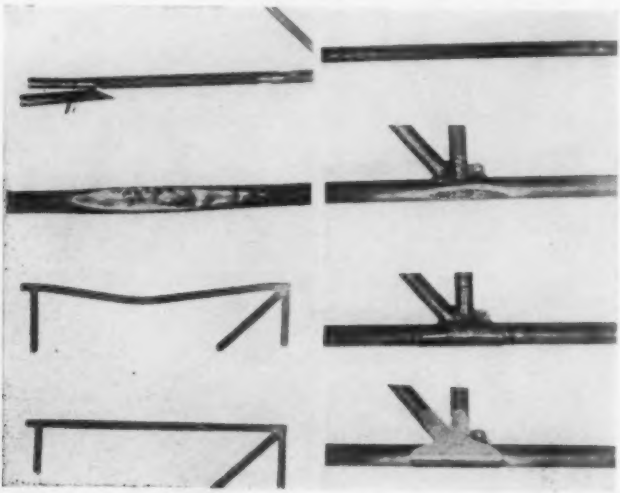


FIG. 13. METHODS OF REPAIRING WELDED TUBULAR STRUCTURES

whether built of wood or metal, which is fastened together with rivets, bolts, or other mechanical devices, will sooner or later loosen up at the joints and a complete overhaul is necessary, generally involving the replacement of several parts. A welded structure is rigid and cannot develop play in the joints. If it is damaged by a crash it can be repaired at the damaged section and will have a strength equivalent to the original structure. The facilities for making repairs are available everywhere. Several methods of repair are shown in Fig. 13. The instructions issued for the repair of welded structures by the United States Army Air Corps contain the following precautions:

"No splices shall be made in structural members (longerons, spars, interplane struts, and landing struts) by butt welds subject to direct tension or bending stresses, unless the joint is reinforced by riveting, pinning, telescoping, or other auxiliary means.

"Welded joints shall not be cleaned up by filing, as such treatment causes a loss of joint efficiency. Welded joints shall not be filled with solder, brazing metal, or any other filler. The joining of parts by filling holes with fused welding wire in lieu of a rivet or bolt is not permitted.

"No welds shall be made over a failure in an electric weld. The cast structure of the electric weld shall first be removed by chipping off before welding with the oxygen-acetylene torch.

"The parts to be welded shall always be cleaned by sand-papering or by wire-brushing.

"In a telescope joint, the splice shall be made with a fish-mouth form or diagonal cut so that the wall of the tube will not be heated at a certain cross-section as in the case of a butt weld. Where practical, the fish-

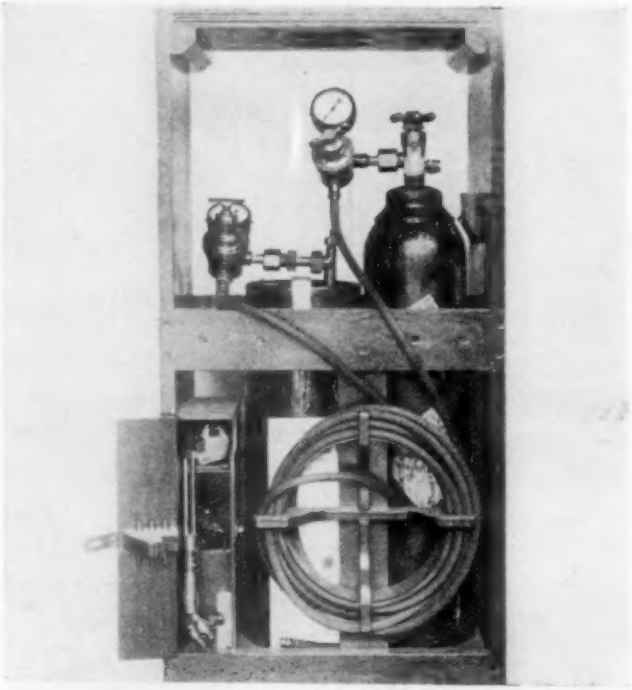


FIG. 14. PORTABLE WELDING OUTFIT FOR EMERGENCY FIELD REPAIRS

mouth shape splice shall be used in preference to the diagonal shape splice, as it permits a better welded bond of the tubes. The length of the cut as measured on the outside wall of the tube shall be not less than one diameter of the tube and preferably two diameters of the tube. The ends of the prongs shall not be appreciably rounded or flattened.

"The splicing shall be done as close to the strut point as possible, since a tubular member is under greatest stress in the middle and the full strength in that portion of the tube should be retained.

"Misalinement of the tubular structure during welding, due to contraction and expansion of the metal, can be prevented by using wood braces with notches in the ends to hold the tubes in place. Care shall be exercised to maintain the true alinement of the strut structure when

new tubes are used to replace the bent or damaged ones. This can be done by measuring the distance between strut points of corresponding members which are not distorted and by reference to the drawings when available."

The United States Army has developed a kit for emergency use, Fig. 14, which, together with a welder, can be carried in any two-place airplane and set up alongside an airplane in the field.

Welding Aluminum Tanks

The fuel tank, which is an essential accessory to the airplane, has been the subject of considerable experimentation and development. The tanks used ten years ago were generally made of tin plate, although in a few cases brass and copper had been tried. These tanks were satis-

TABLE IV

Weight in pounds per gallon of gasoline capacity as determined for various designs of tanks

Welded aluminum	.40–0.62
Terne plate	.72–0.86
Brass	.84–1.01
Monel metal	1.03
Stainless iron	1.00
Copper	0.86

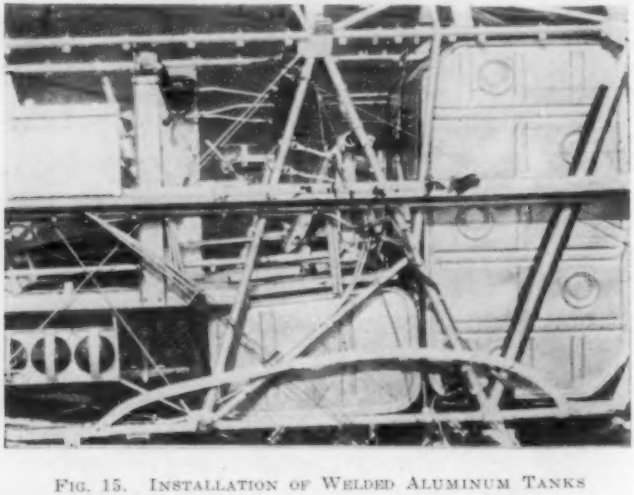


FIG. 15. INSTALLATION OF WELDED ALUMINUM TANKS

factory, in that they were durable and easy to repair. The weight, however, of a fuel tank made of these materials is a disadvantage. The logical method of reducing the weight was to change to a material with a lower specific gravity. Ninety-nine per cent aluminum sheet and the strong aluminum alloys come in this class. A comparison of the weight per gallon of gasoline capacity, as shown in Table IV, indicates that the welded aluminum tank is only a little more than 50

per cent of the weight of similar tanks made from the other commercial sheet metals. The strong aluminum alloys should be heat-treated after welding, which is a disadvantage and has retarded their use. Additional protection to resist corrosion is also necessary with a strong aluminum alloy tank.

The methods of fabrication used in connection with coated steel and brass could not be used readily with aluminum inasmuch as no satisfactory aluminum solder has been developed which has strength and corrosion resistance and at the same time will wet a surface and flow

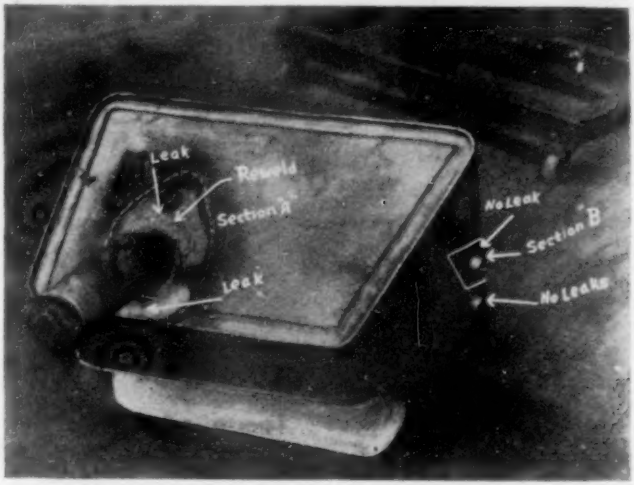


FIG. 16. WELDED ALUMINUM TANK SHOWING A FAILURE IN THE JOINT BETWEEN THE ALUMINUM CASTING AND THE SHELL

easily into a joint. There was some difficulty experienced by aircraft companies when welding with the oxy-acetylene torch was first applied because of the inexperience of the welders in handling aluminum, but this has been overcome to a large extent, and the majority of tanks, where weight saving is a primary consideration, are made of welded 99 per cent sheet aluminum. The fittings on these tanks, instead of being made of brass and bronze with a specific gravity greater than eight, are made of aluminum alloy castings with a specific gravity of less than three.

Welded tanks range in capacity from 25 to 150 gal., although these by no means represent the limits, for welded tanks with greater capacities have been constructed. The large, flat plate area of these tanks makes it desirable to use a slightly heavier gage than would be used for brass or coated steel. Tanks of 0.032 and 0.40 gage have been found to require more maintenance in sizes of approximately 110 gal. than tanks of 0.051-gage material.

Cylindrical tanks of heavier gage (0.081), without baffles, have also been used successfully. Care must be taken that a corrugation, rosette,

or some other means of compensating for the expansion and contraction of the aluminum during welding is incorporated in the design. The tanks shown in Fig. 15 illustrate methods which have been successfully employed.

Welding Auxiliary Tank Connections

The problem of fastening the auxiliary connections, such as filler-neck, flanges for gage connections, dump valves, etc., has received special attention. Fig. 16 illustrates a tank with which difficulty was experi-

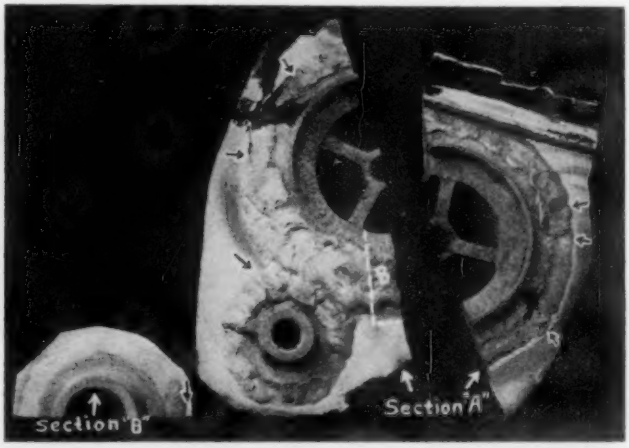


FIG. 17. ENLARGED VIEW OF THE WELDED SEAM, SHOWN IN FIG. 16, WHICH FAILED

enced on account of the filler-neck breaking away at the weld because of vibration. An examination of the joint indicated that cracks had been caused by unequal heating and cooling during the welding process. Attempts to reweld to stop the leaks were not successful, since there were no means adopted for taking care of the expansion and contraction of the sheet. The character of the cracks is shown in Fig. 17. It will be noted that the welding of the casting distorted the sheet. These failures can be remedied by a circular corrugation in the sheet around the joints of the filler-neck casting and the top of the tank and by separating the two castings a sufficient distance so that the welds will not interfere.

The material which has been used for these castings has been the standard foundry alloy containing 8 per cent copper and known as S.A.E. No. 32. A more satisfactory alloy would be one which would have less shrinkage and would flow more easily under the torch, such as the 5 per cent silicon-95 per cent aluminum, or the 4 per cent copper-3 per cent silicon-93 per cent aluminum alloy.

The welding rod generally used for welding tanks has been the 99 per cent pure aluminum. Recent experiments indicate, however, that a rod containing 95 per cent aluminum and 5 per cent silicon is better for this purpose, especially for joining the castings and the sheet metal. The same flux is used with either type of rod. The 5 per cent silicon-

aluminum rod produces a better weld than a commercially-pure aluminum rod, since its initial melting point is about 1070 deg. Fahr., or approximately 150 deg. below that of pure aluminum sheet. The silicon also has the advantage of solidifying over a range of temperatures and has a low solidification shrinkage which allows it to absorb the temperature strains set up in welding. There is very little difference in the tensile strength of joints made with either type of rod, as tests made on pure aluminum strips welded with both types broke at about 13,000 lb. per sq. in. outside of the weld in the annealed aluminum strip.

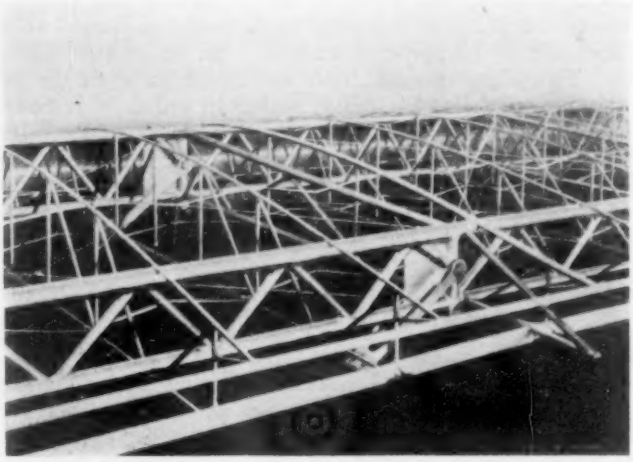


FIG. 18. CHROME-MOLYBDENUM BEAMS AND ALUMINUM ALLOY RIBS

The corrosion of the castings which form the accessories of the gas tank is also important, and in this particular the silicon-bearing alloys, especially the 5 per cent silicon, are much superior to the 8 per cent copper alloy. The machinability of the former, however, is not so good and the alloy mentioned above containing 4 per cent copper, 3 per cent silicon, and 93 per cent aluminum is a good casting alloy which has good machinability and also welds satisfactorily.

United States Army Air Corps Instructions

The following instructions, which have been prepared by the United States Army Air Corps, govern the repair of aluminum welded tanks in the field:

"*General*—The welding of aluminum does not present any particular difficulties if the welder realizes that the melting point of aluminum is much lower than that of steel and, therefore, requires less heat and more rapid manipulation. The melting is most successfully done with the oxy-acetylene torch.

"*Welding*—When it is desired to join the edges of sheets, the flange type of weld is used. The edges to be joined are bent up an amount equal to about three times the thickness of the sheet. A flux is applied

to both sides and the edges are then held together by small clamps and tack-welded at intervals of about one inch by melting the metal together at these points, touching up if necessary with welding rod made from a strip of the original sheet. The clamps are then removed and the weld is completed by melting down the flanges, holding the torch at an angle of 45 deg. with the work and in line with the weld and progressing at a uniform speed. Little or no metal is added from the welding rod. A round and smooth bead should be formed, well rounded on both the upper and lower surfaces.

"If there is considerable oxide or heavy film on the sheets, the edges should be cleaned prior to flanging by immersion for 10 to 30 seconds in a hot solution of 10 per cent caustic soda or 10 per cent tri-sodium phosphate. The edges should then be rinsed in a dilute 10 per cent nitric acid solution, followed by hot water in order to remove all traces of flux, as this flux has a tendency to corrode the sheet. The immersion should not be longer than necessary to clean the surfaces. If the aluminum sheet is fairly clean, a wire brush or steel wool can be used in place of the cleaner. It is not always necessary to use a welding flux if the surfaces are clean, but if trouble is experienced, any good commercial flux may be used. The flux should be applied to the surfaces to be welded, and to the welding rod, with a brush. If the metal is slightly heated the flux will adhere and dry quickly.

"In joining fittings or sheet metal parts to the side of sheet, the usual fillet type of weld is required. After cleaning and applying the flux in the usual manner, the parts are tack-welded together at intervals by small applications of metal from the welding rod. The weld is then made by melting in a filler rod, fusing well with both sides of the joint. In this type of weld special care is necessary to avoid burning through the sheet.

"Welds are very liable to pull out unless provision is made for expansion of the metal during welding. This is generally done by depressions or corrugations in the sheet.

"*Cleaning after welding*—All traces of flux must be removed promptly after welding. Incomplete removal of the welding flux will cause corrosion. The flux can be removed by a scrubbing brush and hot water, followed by rinsing in running water or by treatment with a dilute solution of 10 per cent of either sulphuric or nitric acid, followed by rinsing in cold water."

The Welded Fuselage Has Proved Its Worth

There is a type of airplane structure in this country which might well be called standard. It has a welded steel tube fuselage, landing gear and tail skid. It has been developed in order to obtain maximum strength and rigidity with minimum weight and to use methods which are applicable to small or large production at relatively low cost for material, labor and overhead.

The safety factor in welded construction has been amply demonstrated. It has been used in the fastest racing planes and in the largest bombers

and transports. Many an embryo pilot owes his escape from injury to the resilient, crashproof, military training airplane with its welded steel tube body and undercarriage. There are few well-informed aeronautical engineers and constructors at the present time who have not been convinced that welding is a safe and reliable method for joining steel. The airplane the next few years will be similar to the modern craft. Production costs will be decreased. The oxy-acetylene industry must assist the airplane manufacturer in this respect in order to maintain the present position of oxy-acetylene welding.

The elimination of wood in the wing structure will be accomplished for a number of designs within a comparatively short period. The structures will probably show a greater diversification in the selection of material and methods of manufacture than other parts of the airplane, but the application of welding has a promising future. The welded and heat-treated wing beam is one adaptation which gave a high load factor when tested in competition with wood and riveted aluminum alloy beams. The combination of steel-tube wing beams and drift bracing and aluminum alloy ribs, as shown in Fig. 18, illustrates the advantages to be gained in the use of the two metals in one structure. The multi-spar, welded monoplane wing is an interesting development of a structure in which all of the component parts are tubes and all the joints are made by oxy-acetylene welding. The advantages are torsional rigidity and minimum deflection of the large, internally-braced cantilevers. These examples are additional of the acceptance by engineers of the wide applicability of torch welding to structures which are designed with high unit working stresses.

Training and Management of Welding Operators for Pressure Piping, Tanks and Vessels*

H. H. Moss†

IT is proposed to show that specifications for and management of welding in construction is no different than that required for other methods of construction.

In any case, proper plans and specifications are essential to a satisfactory result. In their development, the executive concerns himself only with the translation of the requirements for the job, he seldom bothers about the details employed in their production. Such matters are generally left to the judgment of those responsible for their production. Through competent inspection, he is assured that his requirements are fulfilled.

In the case of welding, the same steps are applicable and will produce satisfactory results if the requirements upon the welding organization

*Presented at joint meeting Metropolitan Section, A.W.S., and A.S.M.E., January, 1929.

†Engineer, Development Department, Linde Air Products Co.

have been properly determined for the service to which the welded part will be subjected.

To make these determinations, the average executive feels that he or his engineering staff should have considerable practical welding experience, and many attempt to keep informed on the actual production of welding, its technique and its many special characteristics.

The average man, however, does not have the time nor opportunity to do this. It requires careful consideration of the many factors involved in Welding Procedure Control and this is no simple matter. In the first place, should he undertake a proper study of construction welding he cannot proceed very far before he finds that in many instances different authorities on welding offer different solutions for welded construction of the same class. Also he is confronted with the problem of determining which of several welding processes he should employ to provide the best results, all being logically defended by their sponsors.

The result is often that he either refers his welding problems to one or more authorities on welding in the field in which he is working or, as frequently happens, defers the use of welding until he has time for the proper study and determination of suitable welding designs and construction procedures.

Calling in consultants until such time as his own organization has attained proper knowledge of welding is certainly to be recommended and mechanical engineers who are consultants should fit themselves to advise properly in this regard. Unfortunately there are many cases where welding is not considered because of the inability of an executive to give it his personal attention and the many advantages of the welded joint, such as its higher strength, its possibilities for weight economy, lower first cost, lower maintenance cost, etc., are not realized. If welding is not understood as a construction method its outstanding advantages in making alterations and repairs are probably not utilized either.

Today we cannot question the ability of welded construction to meet requirements that operating service demands, particularly where lower carbon steels are used. There are countless precedents that point to the suitability of welding for pressure vessel, piping and structural work, both based on jobs done and on major research work. The applications of welding in the gas and oil industry, where the need for strong, tight joints has resulted in a study of welding and use in almost every direction, show to other industries what they may accomplish.

The question is, and one which logically suggests itself, "What standard and simple means are there available to engineers by the use of which they can be sure of obtaining satisfactory welding for their construction, similarly as they do with other methods of fabrication."

Before going into the solution, let us consider for a moment the recourse of executives with regard to the determination of adequacy of other parts of their construction than welding to meet certain operating requirements and see if we cannot deal with the welded part in a similar manner. A welded joint is a part of our construction as any other joint or assembly of material is a part of it.

For illustration, take the mater of Valve, Flange and Fitting Materials for high temperature service. Your specification will in most cases properly refer to A.S.M.E. Boiler Code Specifications covering these materials. These code specifications will state that the castings shall conform to a certain chemical composition and the manufacturer is called upon to specify the limits of chemistry which they will accept as a basis for rejection. A Ladle analysis and check analysis is demanded.

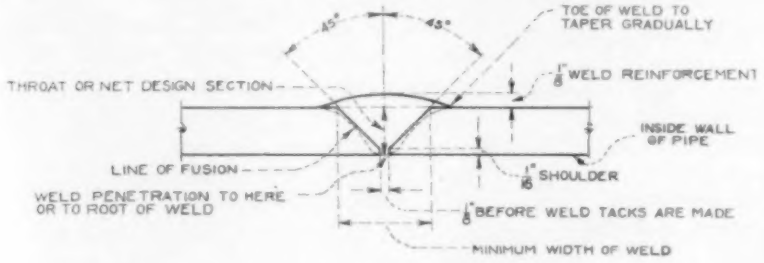

45°
45°
TOE OF WELD TO TAPER GRADUALLY
THROAT OR NET DESIGN SECTION
1/8" WELD REINFORCEMENT
INSIDE WALL OF PIPE
LINE OF FUSION
1/8" SHOULDER
WELD PENETRATION TO HERE OR TO ROOT OF WELD
1/8" BEFORE WELD TACKS ARE MADE
MINIMUM WIDTH OF WELD

FIG. 1
DESIGN FOR BUTT WELDED JOINT

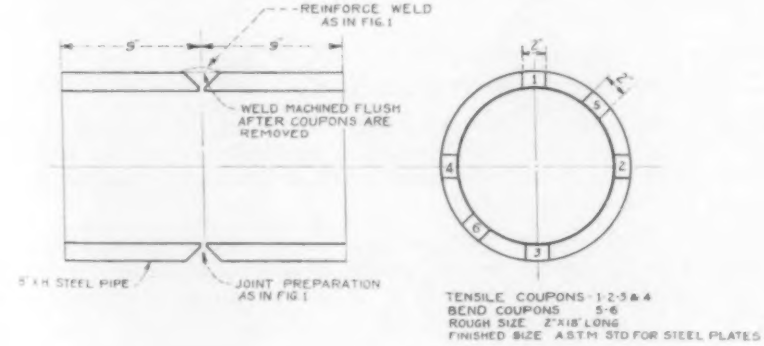


FIG. 2
DESIGN FOR TENSILE TEST SPECIMEN

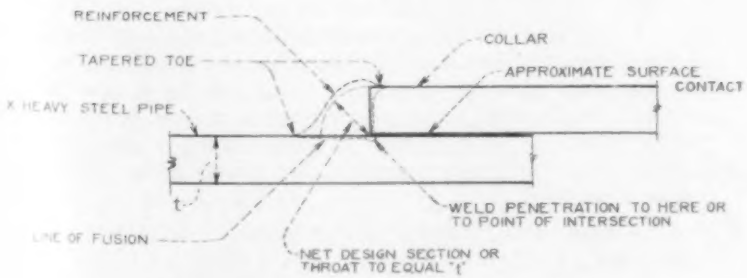


FIG. 3
DESIGN FOR FILLET WELDED JOINT FOR PIPING

Certain physical requirements are set up and many other detail checks are provided to insure serviceable material. Heat treatment is properly covered. Any castings which do not conform to these specifications or which show injurious defects are promptly rejected by your inspector. Bolts and nuts are given similar consideration. The same is true for materials for piping and pressure vessels.

In a piping specification, for instance, we require conformity of materials to definite specifications for the following factors:

Process of manufacture
Chemical composition
Tension tests
Hydrostatic tests
Flattening tests
Bend tests
Test specimens
Number of tests
Retest
Standard weights
Permissible variations
Lengths
Workmanship
Ends
Finish

All in all, a rather stringent specification.

Again, in the matter of flanged joints for piping, we generally explain in our specification just how they shall be made up by the fitters or manufacturers and frequently make trade references to emphasize the quality of the product intended.

If dealing with special materials or alloys whose specifications are not reduced to standards, we are careful to specify in detail the properties and methods of evaluating their properties in order to insure adequacy to the service in which they will be utilized.

For all of these specifications there is a co-factor, namely, design, which provides for the proper application of the materials. Inspection is introduced and upon this we depend for the carrying out of the design and specifications.

The solution of a problem where welding is contemplated can be made in the same manner. It requires consideration of the factors that make up welding procedure control, wherein is contained the factor that deals with production of the weld, or, as we are more or less prone to regard it, the "human element" in welding. If you look upon this problem in the same manner in which we regard it for other methods of fabrication, it can be simplified.

First, let us draft a key or list of the essential factors to be dealt with. There are:

A. Materials for welding.
B. Design for welding.

C. Qualification of welders.
D. Final testing.

One very important step in procedure control is omitted in this list, namely, shop practices, because it is generally difficult to specify such things as methods of clamping parts together, spacing to be allowed, etc. In a shop where the personnel is experienced, as is demonstrated by having done satisfactory work, these practices have been taken of.

Under the heading of "Materials for welding" we have two materials tc consider—the base metal and the welding rod.

Both may be specified, as for other types of fabrication, by—

1. Chemical analysis.
2. Physical test for strength.
3. Physical test for ductility.
4. Process of manufacture, etc.

And the rods may have additional tests for weldability and for strength of deposited metal.

To simplify matters, quality of base metal can be called for to comply with suitable A.S.M.E. specifications or American Standards. Rod specifications can be called for in suitable standards that have been developed.

Frequently a selection must be made from several types of base metal and several types of rod. The needs are the controlling factors, except that it should be remembered that the highest quality is usually the best in the long run. But this is not different in principle than for riveted construction or flanged pipe installations where the type of material must be specified.

Design for welding, which will result in the joint being made at the most suitable place and of the most suitable type, should be handled by some trustworthy engineer or draftsman who is familiar with welding requirements. This is really much simpler than for other types of construction. A little aid may be useful on the first job or two but such aid can be readily obtained today by the executive who desires to use welding.

It is much less difficult to select between the butt weld type made from two sides, a single Vee butt weld, a double fillet weld or a single fillet weld, than it is to select and lay out the correct riveted design between such extremes as quadruple double butt and single lap riveted joints.

Standards of strength for the several types of welds with different quality materials may be obtained from the welding industry in a few hours or minutes time and then what is called for is welding performance by the welding organization in actual construction. It is relatively easy to obtain welds that will consistently average above the minimum strength of flanged quality steel and thus develop in the joint the full strength of the material.

Under the very important heading "Qualifications of Welders" we find an addition to fabrication specifications. No specifications call for tests

of the strength of riveting but there are distinct variations in quality of riveting with regard to such things as punching or drilling holes, alignment, reaming and the use of full sized rivets. In other words, workmanship is a distinct factor. The inspection for workmanship and the final test are expected to take care of these matters.

Now in welding, to be reasonably sure of performance, each executive specifying welding should require a qualification test of each welder who will be allowed to work on the job. A certified test on similar material made within a specified time should be employed, but a good test on say 3/16 in. material would not qualify a welder for work on a ½ in. thick plate, let alone ¾ in.

As an illustration of a suitable qualification test the following it taken from an actual case applying to gas welding construction for 400 lb. pressure super-heated steam piping system, maximum temperature 750 deg.:

General

1. Only competent gas welders, having experience in welding steel piping of the sizes involved herein shall be employed for the welding of the piping covered by these specifications.
2. Any welder employed for this work shall be required to pass the following qualification tests before starting work of welding on any of the piping to be welded under this specification.
3. The contractor shall at all times during the course of construction maintain on file for the inspection of the beginner or his authorized representative, a record of the welders employed for this work, together with a copy of report of the results of each welder's qualification test as required herein.
4. The qualification of welders shall be arranged for by the contractor within —— days after the formal award of contract, and shall be done in the presence of engineer or his authorized representative. This may be done in the contractor's shop or on the premises of the work. The contractor shall notify the engineer ——days in advance of the date set for the qualification test.
5. The material for these tests shall conform to the material specifications herein for piping and welding rods.

Leak Proof Test

This test requires the welding of the joint in one pipe bomb to be made up of 6 or 8 in. extra heavy pipe containing two circumferential position butt welds approximately 8 in. apart, one of the joints to be welded with the bomb lying horizontally, the other to be welded with the bomb erection vertically. The bomb shall not be rotated during welding. The preparation of the joint shall coincide with the welded joint detail as shown on engineer's drawing. (See Fig. 1.) Weld reinforcement to be ⅛ in. gradually tapered where it approaches the base metal. Penetration shall be to the inside wall of the pipe. The ends of the bomb are to be closed in a suitable manner to withstand the test pressure to which it shall be subjected. At completion of welding and after the bomb has cooled to room temperature, the bomb shall be subjected to

an hydrostatic test of 600 lb. per sq. in., or 1½ times working pressure, after all air has been expelled therefrom. While under this pressure the welds shall be struck with a 4-lb. sledge at four equidistant points, the blows being struck with a full arm swing. Under these conditions the welds shall not leak or develop any visible imperfections.

Tensile Test

This test requires the position welding of a joint between two pieces of 8 in. extra heavy pipe, 9 in. long, to form a single piece of 8 in. dia. x 18 in. long, as shown in Fig. 2. The joint edge and reinforcement and penetration shall be specified similarly to that for the Leak Proof Specification above. The pipe shall not be rotated during the welding operation.

Upon completion of welding and the cooling of pieces to room temperature standard tensile test coupons shall be taken therefrom, one from the bottom of the joint, one from the top of the joint and one from each side of the joint, four in all, and be tested by a recognized testing laboratory to rupture, at a testing speed not to exceed ⅜ in. per minute within the yield point. All weld reinforcement shall be removed by machining or grinding. Under this test the coupons shall break outside of the weld or otherwise, develop an average tensile strength of not less than 52,000 lb. per sq. in., with a minimum tensile strength of not under 50,000 lb. per sq. in. The cross-section surfaces of the coupons at the weld shall show complete fusion and penetration to the bottom of the Vee.

Ductility Test

When this test is required, two additional coupons 2 in. wide x 18 in. long are taken from the tensile test specimens between the quarter points. This test requires that the coupons be clamped in a vice with the edge of the weld in line with the top of the vice jaws, in which position the exposed section of the coupon shall be gradually rotated in either direction until the section is bent through an angle of not less than 90 deg. Under this test the weld shall not develop any visible surface cracks or fractures.

The above qualification tests consider only the butt type weld. For fillet welding adequacy is determined similarly. It is necessary, of course, where fillet welds are used to provide a test specification that utilizes this type of weld. A collar or bell and spigot joint is called for and upon completion of welding cross-sections of the fillet are inspected for fusion and penetration. (See Fig. 3.) The strength of fillet weld metal is generally determined by testing a butt weld made by the same welder, however, a tensile specimen having fillet welds can be easily made up.

Some very interesting recent test results of both the butt and fillet welds on piping are reported in the American Gas Association 1928 Report of Sub-Committee on Pipe Joints covering pipe sizes from 4 in. to 8 in. inclusive. From these data suitable specification design data could be easily obtained.

For other conditions than those governing the above specifications the qualifying test can be readily modified. A leak proof test for the low pressure or vacuum service piping can be made on much smaller diameter

piping, thereby reducing the cost of qualification of this class of piping. The tension test requirements are generally not made as stringent, care being exercised only to see that a sufficient strength is demanded to eliminate the unskilled operator.

Training

When a welder fails to pass a good test it frequently means that he is not well advised as to correct penetration and the correct amount of heat to use. A very short period of instruction under a competent man will generally be ample. But qualification tests have proved to be the best trainers of welders because the results put it up to the men.

By the use of exacting qualification tests the burden of training is placed on the welding operator himself. In plants or in organizations where considerable welding is done mechanics and men of other mechanical trades, as well as helpers who take an interest in welding, are often permitted, after they become fairly proficient by practice and elementary instruction, to do the less important work. These men, if they show sufficient proficiency to indicate an adaptability to welding, are frequently coached until it is possible for them to pass the required qualification tests for production welding. No such man should be permitted to work on specification welding until he is able to pass the qualification test demanded, however, and it is an important matter for the inspector to see that this provision is rigidly enforced.

Final Testing

One of the most important points for the management is the final test. If inspectors have seen that the various steps called for in good specifications have been followed, then the final test should insure that the job is going to give satisfaction. The type of test that will be a proof test should be given very thorough study.

Upon completion of any welded vessel or piping it is customary to test hydrostatically to three times the working pressure for weld strength. Subsequent air tests at reduced pressures can be made if desired. For piping systems 1½ times the working pressure is frequently considered sufficient and quite often in steam lines the safety valve blow-off pressure is taken. Headers and specials are generally tested to three times under pressure.

For inspection of welding, if the organization does not have a qualified inspection staff, there are several commercial testing laboratories now fitted to render this service. Furthermore, several of the larger laboratories of companies interested in the promotion of welding will gladly aid in training employees of purchasers of equipment so as to obtain satisfactory shop inspection.

To sum up the situation under procedure control, the present-day executive can have welding specifications drawn up so as to check each step in welded construction and place the responsibility for trouble where it belongs should the final test not be met.

This is exactly what he does with other methods of fabrication where he calls for certain results to be proved by test. He doesn't worry about correct practices because he provides inspection to see that specifications are carried out.

Welding of Frogs by the Havana Electric Railway Co.

C. ARNOLDSON†

THE frogs in the following photographs have been made in the welding department of the ways department under my supervision and direction.

Photograph No. 1 is a double frog all arc-welded made up into one solid piece of steel without the use of bolts, rivets or fish-plates, using ½-in. ordinary steel plate to tie 108 lbs. Lorain (high guard) girder rail; one rail is curved, (note good curvature,) and the other two are straight. This double frog is to replace a worn-out factory made frog of the Ironbound Guarantee Insert type. We also make these frogs for new work. This home-made frog costs including labour and material $89 while the same from the factory costs about $450.

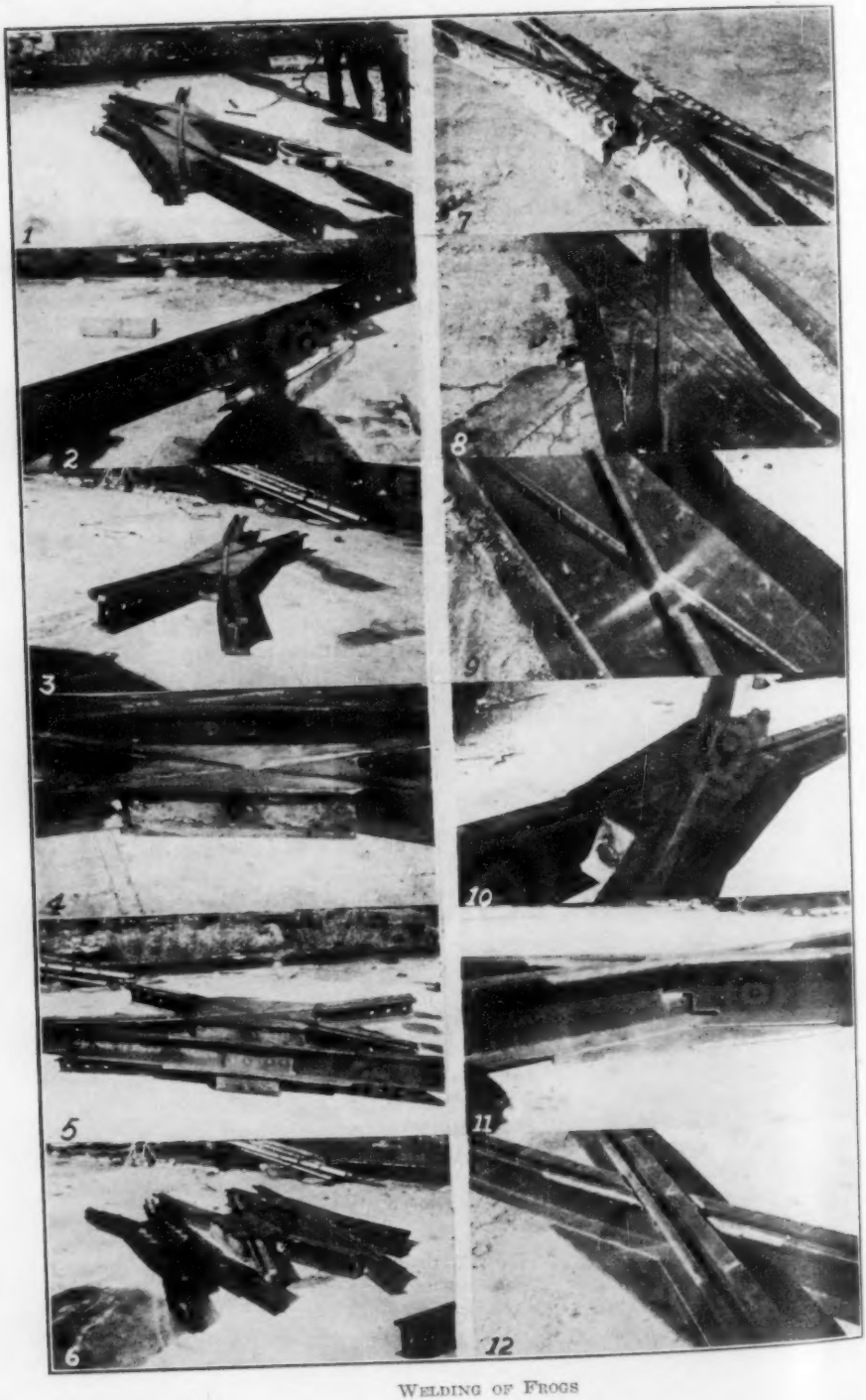
Photograph No. 2 shows side details of welding in frog of photograph No. 1. Photograph No. 3 shows a single frog home-made all arc-welded with vertical side plates ½-in. thick to imitate the center casting of a factory-made frog. This frog was specially made to demonstrate that we could make a frog by welding not only as strong as a factory-made one but also to look like it in every respect, even in the casting. The cost was $50 while the cost of the factory-made one would be about $250.

In photograph No. 4 there is in front a close-up view of the center part of the frog of photograph No. 3. In back you can see a side view of the home frogs we usually make without the vertical side plates which imitate the casting; these cost from $42 to $45—you see still cheaper than the one in No. 3; as the vertical side plates are only for looks and do not greatly strengthen the frog, the extra cost is not warranted and we omit them.

In photograph No. 5 you can see clearer the side appearence of our ordinary frogs without the vertical side plates, and in back you can see the frog of photograph No. 3 imitating the casting of the factory-made ones.

In photograph No. 6 you see on the extreme left of the picture a factory-made frog costing about $250. This is of the Ironbound Guarantee insert type. In the center of the picture you see our home-made frog of photograph No. 3 imitating the factory-made one even as to casting, and costing $50, and finally on the right of the picture you see one of our usual home-made frogs ranging in price from $42 to $45 depending on whether it is single or double curved; so you can see these are still cheaper and what a saving they effect.

†Engineer of Ways, Havana Electric Railway Co.



WELDING OF FROGS

We make a frog in about three days, while it takes about three to four months to order same from the States, so we do not have to worry about our factory-made frogs breaking down under traffic, due to the casting (cast-iron) failing or the hard center insert breaking beyond repair, because in about three days we have a home-made one in its place. Our home-made frogs cannot fail, they can wear down under traffic and we weld them to the proper shape repairing the flangeways and points with high-carbon or manganese welding wire depending on the traffic conditions; this we have to do also to the insert plate of the factory made frogs.

Factory-made frogs fail under traffic at the casting. Photograph No. 7 shows a typical break. Sometimes when new if they are accidentally dropped due to careless handling, they break or when in the track only a short time due to a flaw in the casting. In our home-made frogs we have eliminated the weak point which is cast iron. Sometimes the hard center insert becomes loose and breaks, or due to repeated repairs by electric welding the crystalline structure of the material is changed and weakened and the plate breaks badly, and if the rest of the frog is badly worn it does not pay to put in a new insert plate. Our frogs are one solid piece of steel after welding the different parts together with mild steel wire. For the wearing portions on the center of the frog we use high-carbon or manganese welding wire. In photograph No. 8 you see the center top part of a home-made frog before grinding, and in photograph No. 9 you see it after grinding, photograph No. 10 shows the center top detail of the frog of picture No. 3. We reinforce our frogs with plates in every direction possible.

We use the oxy-acetylene torch to cut the plates and rails so as to fit them into one another. We never cut any of the rails clear through, but cut enough of each so as to frame into one another. Straight rails are cut at the top, leaving the flange and a part of the web continuous, and the curved rails are cut at the bottom flange, leaving the top, guard, ball and part of the web continuous. In photographs Nos. 11 to 12 inclusive you can see how the cuts and framing are made.

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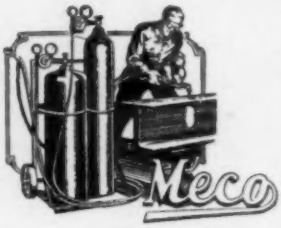

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